Paolo Attivissimo

MOON HOAX: DEBUNKED!



Finally, a no-nonsense, fact-filled rebuttal of "moon hoax" claims, for doubters and enthusiasts alike

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2020 Edition

You've heard the "moon hoax" claims. You know they're wrong. But can you explain why?

Now you can.

Finally, there's a no-nonsense, fact-filled e-book that debunks "moon hoax" claims.

This book is intended not only **for open-minded doubters**, to dispel their understandable questions about what is even today an incredible series of voyages, but also **for space enthusiasts**, who will find concise, plain-language but technically accurate answers that they can offer to their doubtful friends and use to quash the quibbles of conspiracy theorists. This information may come in handy especially for **anyone giving talks about space**.

Examining and debunking conspiracy theories is also a great way to tell the real, fascinating story of how we went to the Moon between 1969 and 1972 and to discover many of the true secrets of this adventure. Did you know that the Soviets also tried to land a cosmonaut on the Moon? That many of the missions almost ended in disaster? Or that *Playboy* pictures were smuggled all the way to the lunar surface?

Moon Hoax: Debunked! is fully available for free at
MoonHoaxDebunked.com

Dispelling doubts about the Moon landings, celebrating courage and ingenuity.

Cover: Gene Cernan during his third moonwalk, Apollo 17, December 1972. NASA image AS17-140-21391. The image has been cropped and the sky has been extended digitally to fit the book layout. Credit: NASA.

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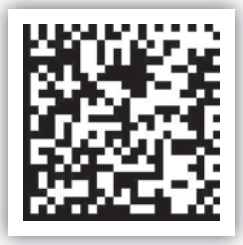
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About me



Paolo Attivissimo (right) with Buzz Aldrin (left), one of the first two astronauts to land and walk on the Moon. Credit: Andrea Tedeschi Photography.

I'm Paolo Attivissimo, a British-Italian science journalist specialized in research into conspiracy theories, hoaxes and urban legends. I've written or coauthored over a dozen books on computers, the Internet and other subjects such as 9/11 conspiracy theories, UFOs and science-related mysteries in Italian.

I live near Lugano, Switzerland, where I work for Swiss National Radio (RSI) and as a consultant for RAI, Mediaset and other Italian-language radio and TV networks.

I'm a contributor to NASA's *Apollo Lunar Surface Journal* and I often act as translator for the Apollo astronauts when they visit Italy. As a lifelong space enthusiast, for me *Moon Hoax: Debunked!* is a labor of love as well as a good excuse to delve into the fascinating human and technical details of mankind's greatest journeys of exploration. I hope you'll enjoy reading it as much as I've enjoyed writing it.

Donations and donor list

You can read the full text of *Moon Hoax: Debunked!* for free, but if you fancy encouraging me to update it and extend it, or just offering me a pint of beer to say thanks, who am I to stop you?

If you like, I'll include your name/nickname/company name in the list of donors below.

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Thank you!

Donors

Many donors have asked to remain fully anonymous: here are the ones who have given me permission to be mentioned at least in partially anonymized form. To each and every one, thank you and *ad astra!*

Afsi

Alessandro Marco Galli

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laschip

Preface

Why this book?

Half a century ago mankind first set foot on the Moon. Many of us, including myself, experienced that extraordinary moment as amazing news that filled the papers and magazines and gave us an unforgettable, sleepless night spent gazing at the ghostly live television pictures that reached our homes from another world.

Today, however, to a growing number of people that memorable achievement is literally history: blurred, distant, known only through second-hand stories and often reported tiredly and superficially by mainstream media. Even today, going to the Moon is still an incredible, mythical and unreal challenge, and the idea that we went there in the 1960s – and then *stopped going* – is, for many, understandably hard to accept.

I offer this book to anyone who honestly seeks to understand what really happened and rightly demands answers to his or her reasonable doubts. To hardcore Moon hoax believers, those who are impervious to any argument and think that they have it all figured out, I offer only my pity. They are unable to enjoy this amazing adventure, which is one of the few peaceful endeavors for which the twentieth century stands a chance of being remembered as something more than a heartbreaking series of wars, devastations and genocides.

However, this book is not just a pedantic refutation of a set of eccentric claims. It's a celebration of a moment in time that can never be equaled or repeated. Yes, there will be other destinations, other missions, other landings on distant worlds, but the Moon landing of July 1969 will be forever mankind's first contact with another world. It will always be the first time that humanity proved, albeit for a brief moment, that it is capable of crawling out of its fragile cradle.

What an incredible privilege it is to be alive in that unique, minuscule slice of history in which all this happened, and to be able to personally thank, talk and shake hands with those who accomplished a voyage that for countless centuries was merely a dream beyond the power of even the mightiest king, emperor or pharaoh. *To walk on the Moon*. This book is my small homage to the courage and ingenuity of all those who contributed to turning that dream into reality. In peace, for all mankind.

Paolo Attivissimo

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- my daughters Lisa and Linda, who helped me with the technical process of creating the digital edition of this book;
- my wife Elena, for her endless patience and for organizing my many public talks about the Apollo missions and this book.

I would like to thank all the donors who made it possible for me to make this book freely available online and keep it up-to-date.

This book is dedicated to my parents, who woke me up when I was six years old so that I could watch the Apollo 11 Moon landing live on TV in sleepy amazement (it was nighttime in Europe), and to my aunt Iris, who in the early 1970s gave me a copy of Peter Ryan's enthralling account of the first Apollo missions, *The Invasion of the Moon 1957-70*. I never recovered from this double bite of the space bug. That dog-eared paperback is still here with me as I write these words. Its pages are fading, but the passion and wonder they have fed for all these years are certainly not.

Free distribution

You may freely copy and distribute this book in its digital editions, provided that you don't alter it, don't pass it off as yours and don't print it for sale without my written permission; the details are in the *Copyright notice* section. I didn't write *Moon Hoax: Debunked!* to become rich and famous, but to allow as many people as possible to get the facts they need to counter the arguments of conspiracy theorists. Just don't mess with my rights.

However, writing a technical book takes time and hard work; buying manuals, DVDs and documents takes money. So if you like what you read and you feel like lending me a hand on this project, you're welcome to point out errors or unclear language and help me with research by writing to *paolo.attivissimo@gmail.com* or donate the equivalent of a genuine Italian pizza and a good beer as an incentive for me to keep on writing. A Paypal donation button is available at *MoonHoaxDebunked.com*.

Units of measurement and terminology

Throughout this book, all measurements are given in both metric units and US customary units. Unless otherwise specified, *mile* is understood to reference a statute mile and *ton* is understood to be a metric ton (1,000 kg). Some rounding may be introduced to avoid unnecessarily pedantic conversion results; e.g., 100,000 feet will be converted to 30,000 meters instead of 30,480. Also, idiomatic expressions such as *a couple of inches* or *a few feet*, which suggest a very approximate measurement, will not be converted.

This book uses non-gender specific terms, such as *crewed* and *crewless* rather than *manned* and *unmanned*, except for names of buildings and programs, in accordance with the *NASA History Program Office Style Guide*:

> In general, all references to the space program should be non-gender-specific (e.g., *human, piloted, unpiloted, robotic*, as opposed to *manned* or *unmanned*). The exception to the rule is when referring to the Manned Spaceflight Center (also known as the Manned Spacecraft Center), the predecessor of Johnson Space Center in Houston, or to any other historical program name or official title that included *"manned"* (e.g., Associate Administrator for Manned Spaceflight).

Although I'm half British, I've used US English rules in this book because I know that otherwise I'll get heaps of mail complaining about my "misspelling" of *colour, metre, tranquillity* and so on. Brits, instead, will cringe and bear politely.

Comments, corrections and updates

This book is a work in progress. Apollo's science and documentation are still being studied today and new Moon probes are providing updates and new opportunities for cross-checking that are included here as they become available.

Also, conspiracy theorists concoct new "evidence" and claims all the time, so you might find that a specific claim hasn't yet been debunked specifically in this book. You might also find mistakes or typos. If so, let me know by e-mail at *paolo.attivissimo@gmail.com*, so that the next edition of this book will be updated and corrected.

The changes introduced in the various editions are listed at *MoonHoaxDebunked.com*.

In memoriam

This book wishes to honor those who paid the highest price in order to reach and extend the new frontier, sometimes in secret and often without being remembered even as a footnote of history. The story behind each one of the names that follow is given in the *Remembering the fallen* chapter.

May we never forget that anyone who denies the Moon landings is sullying the memory of these brave people, of their families and of everyone who worked hard for the exploration of space.

Michael J. Adams
Michael P. Anderson
Charles A. Bassett II
Valentin Bondarenko
David M. Brown
Roger Chaffee
Kalpana Chawla
Laurel B. Clark
Georgi Dobrovolski
Theodore C. Freeman
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Ronald McNair
Ellison Onizuka
Viktor Patsayev
Ilan Ramon
Judith Resnick
Francis "Dick" Scobee
Elliot McKay See, Jr.
Michael J. Smith
Vladislav Volkov
Ed White
Clifton C. Williams, Jr.

Ad astra per aspera.

1 Race for the Moon

The idea that the Moon landings were faked is based in part on shallow knowledge of the historical period. This chapter provides some background for anyone who might need it.

If you experienced the 1960s personally, you can probably skip to the next chapter because you remember the period quite well, but you might still find this chapter useful as a quick refresher on the early years of space exploration.

If you weren't alive during those extraordinary years or were too young to remember them, brace yourself for surprises. You missed out on a period of giant leaps in technology and science, not only in the aerospace sector, which changed forever the way the universe was seen and understood, at least by people who were willing to open their eyes, while blinkered and temporary despots inflicted unspeakable suffering on the inhabitants of this tiny grain of sand suspended in the velvet blackness of the cosmos. Those were years when everything seemed possible and what was incredible became achievable.

1.1 Balance of terror

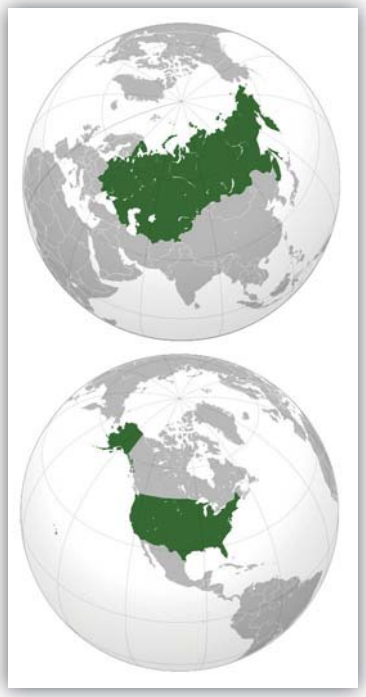


Figure 1.1-1. The Soviet Union and the United States. Image source: Wikipedia.

The time is the 1950s. The United States and the Soviet Union are intently playing history's most dangerous game of chicken, aiming thousands of nuclear bombs at each other's cities, according to a doctrine aptly named *MAD*. As in *Mutual Assured Destruction*. They both know that if one of them decides to attack, the other's nuclear retaliation will lead to utter annihilation.

This fragile balance of terror will last forty-five years and will end with the breakup of the Soviet Union in 1991. But at the time of the Moon race, the Soviet Union is a powerful, secretive superstate that includes the countries now known as Russia, Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Moldova, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

These two military superpowers are vying for control of the ultimate high ground: space. They both view spaceflight as an opportunity to spy on each other and deliver atomic bombs more efficiently and to prove to the world their technological prowess and the superiority of their social system. Space is propaganda.

On October 4, 1957, the Soviet Union stuns the world by launching the very first artificial satellite, Sputnik 1. Western public opinion is all to aware of the fact that Sputnik overflies the US and the rest of the world with absolute impunity and has been hurled into the sky on one of the intercontinental missiles that the Soviets (like the Americans) are building to drop nuclear warheads in mere minutes onto enemy targets.



Figure 1.1-2. Sputnik 1. Credit: Roscosmos.

The United States launches a crash federal program to recover from the political humiliation of being beaten by what was considered by many a backward country. It belatedly accelerates its fledgling space program, which had already achieved remarkable results, such as the first photographs taken from space: towards the end of the 1940s, US researchers had modified German V-2 rockets to perform brief vertical flights to altitudes up to 160 kilometers (100 miles), carrying scientific instruments and cameras. This crash program also seeks to close the academic, military and technological gap that Sputnik has so eloquently exposed. But at first the only result of this effort is further embarrassment.



"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

NEW YORK, SATURDAY, OCTOBER 5, 1957. FIVE CENTS

SOVIET FIRES EARTH SATELLITE INTO SPACE; IT IS CIRCLING THE GLOBE AT 18,000 M. P. H.; SPHERE TRACKED IN 4 CROSSINGS OVER U. S.

HOFFA IS ELECTED TEAMSTERS' HEAD, WARNS OF BATTLE

COURSE RECORDED

Navy Picks Up Radio Signals—4 Report Sighting Device

560 MILES HIGH

Visible With Simple Binoculars, Moscow Statement Says

Device Is 8 Times Heavier Than One Planned by U.S.

FAUBUS COMPARES HIS STAND TO LEE'S

Fla Widens In City; 10% Rate Predicted; 200,000 Pupils Out

ARGENTINA TAKES EMERGENCY STEPS

SATELLITE SIGNAL BROADCAST HERE

Figure 1.1-3. The American press reacts to the news of Sputnik 1.

One month after Sputnik 1, on November 3, 1957, the Soviets set another record with Sputnik 2, taking the first living being into orbit around the Earth, the dog Laika, before the United States has placed anything at all in orbit. Laika dies a few hours later from overheating and stress, but this is kept secret. The flight has been planned as a one-way mission anyway, because the technology for returning living creatures safely from orbit is not yet available.

Finally, on December 6, the US makes its first orbital launch attempt. The Navy's Vanguard TV3 rocket rises a few feet and then explodes dishearteningly on the pad.

The United States manages to place a satellite in orbit on January 31, 1958: Explorer 1 is launched on a Jupiter-C/ Juno-I, a US Army Redstone rocket designed and modified

by Wernher Von Braun, creator of the infamous V-2 rockets that had been used to bomb London and other cities during the Second World War. Von Braun had defected from Germany in 1945 and is now working for the US military.

America is in space at last. Nevertheless, the measly 14 kilograms (31 pounds) of Explorer 1 are nothing compared to the over 500 kilos (1,100 pounds) of Sputnik 2 and the over 1,300 kilos (2,900 pounds) carried into space by Sputnik 3 on May 15.

Ironically, part of the Soviets' lead in space is due to their *inferior* military technology: in the early 1950s both the US and the Soviet Union had developed intercontinental missiles capable of carrying nuclear warheads, but Soviet nukes were heavier than American ones. The Soviets solved the problem simply by building bigger rockets, which happened to be easily adaptable for spaceflight.

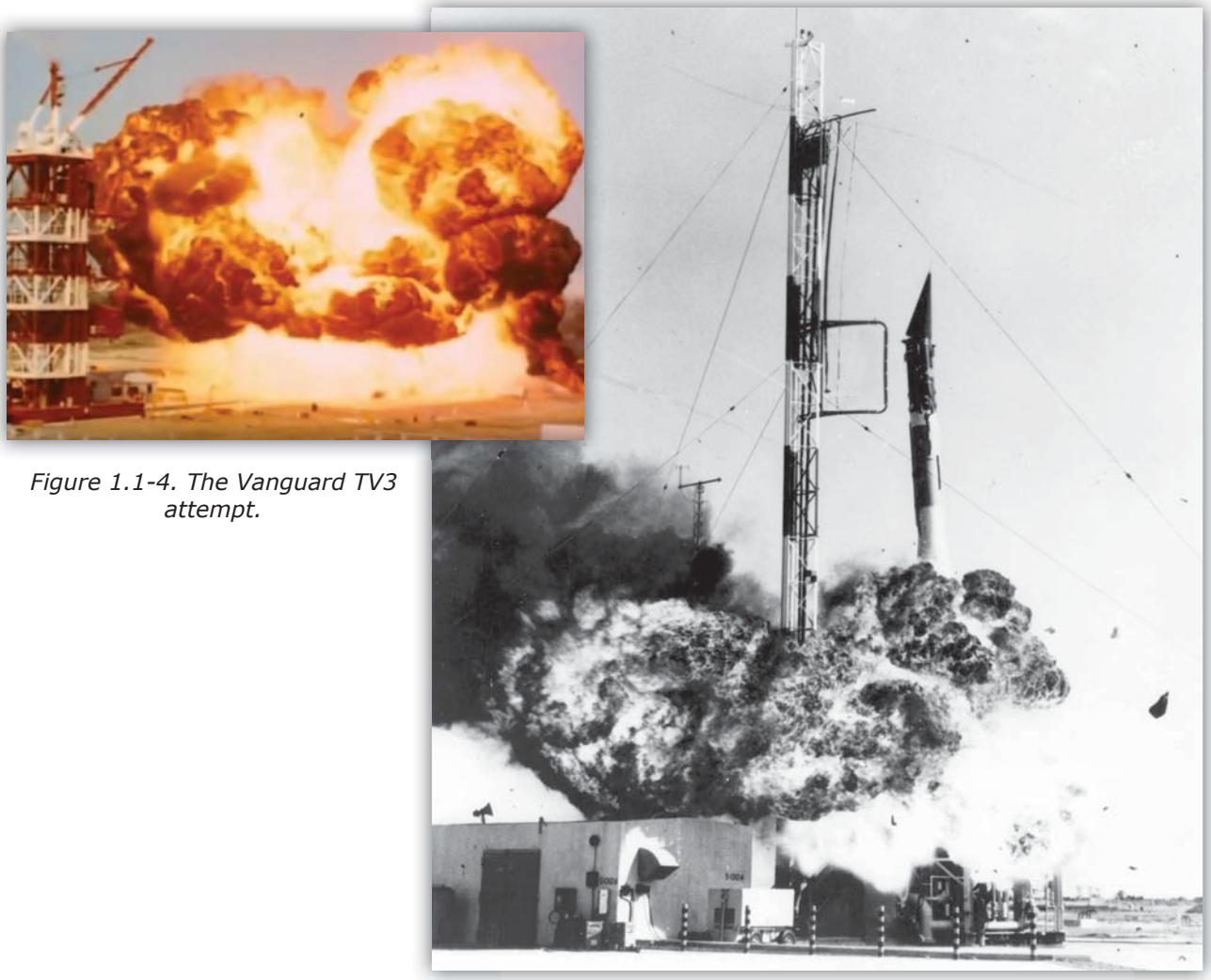


Figure 1.1-4. The Vanguard TV3 attempt.

1.2 The Soviets lead

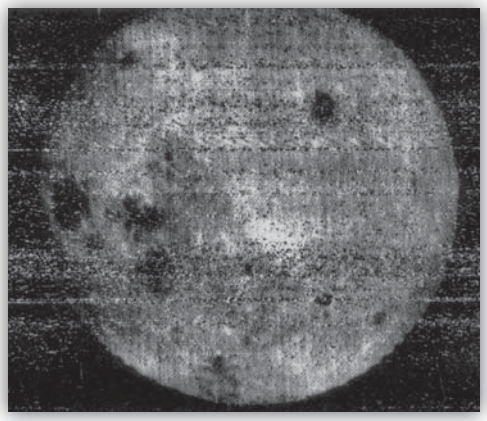


Figure 1.2-1. The far side of the Moon, imaged by the Soviet probe Luna 3 in 1959.

In August 1958, the United States tries to get ahead of the Russians with an attempt to be the first to reach the Moon with an automatic probe, Able 1, but the launch fails 77 seconds after liftoff. The next three attempts (Pioneer 1, 2 and 3) suffer a similar fate.

On January 2, 1959, the Soviets launch the Luna 1 probe, which two days later achieves the first lunar flyby, getting as close as 6,000 kilometers (3,700 miles) to the Moon, and becomes the first vehicle to go into orbit around the Sun.

America's fifth lunar attempt, Pioneer 4, achieves solar orbit but fails to get any closer than 60,000 kilometers (37,000 miles) to the Moon on March 4.

The Soviets achieve another first on September 13, 1959: their Luna 2 probe crash-lands on the Moon. Less than a month later, Luna 3 reveals to the world the very first pictures of the far side of the Moon.

It will take the US five more years, and nine more attempts, to reach the Moon with a space probe. For the time being, America has to make do with science missions in Earth orbit, such as Explorer 6, which provides an almost complete map of the Van Allen radiation belts that encircle our planet and returns the first television pictures of Earth from space. Two monkeys, Able and Baker, are recovered successfully after suborbital flights into space. But the headline-grabbing space launches are all Soviet.

1.3 The US catches up

In 1960 the United States achieves several records: first imaging weather satellite (TIROS-1, April 1), first military electronic intelligence satellite (GRAB-1, June 22), first recovery of a satellite after reentry from Earth orbit (Discoverer 13, August 11) and first imaging spy satellite (Discoverer 14, August 18).

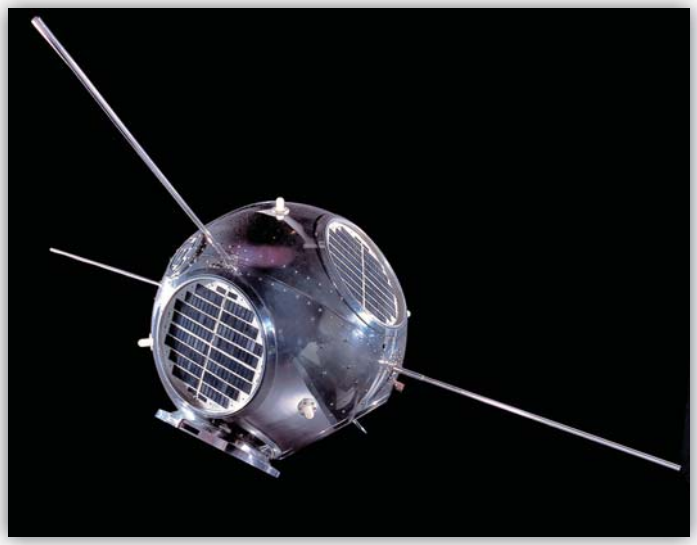


Figure 1.3-1. The GRAB-1 satellite.
Credit: Smithsonian National Air and Space Museum.

These are mostly military achievements, prompted by the need to replace urgently with satellites the top-secret U-2 spy planes that had been conducting covert reconnaissance flights over Soviet territory, taking detailed pictures of the country's most secret facilities. On May 1, 1960, one of these planes had been shot down and the pilot captured, causing huge diplomatic embarrassment to the United States.

Once again the Soviet Union grabs the space headlines: in August, Sputnik 5 carries plants and animals (two dogs, Belka and Strelka, forty mice and two rats) into space and for the first time returns them safely from orbit.



Figure 1.3-2. The remains of the U-2 spy plane shot down over Russia. Credit: Aerospaceweb.org.

1.4 The first human being in space

1961 sees a new Soviet shocker: on April 12, Yuri Gagarin becomes the first human being to fly in space. Not as a brief up-and-down hop beyond the atmosphere, but as an orbital flight aboard Vostok 1.



The Huntsville Times

Where Progress... Covers The Valley!

Feature Index

21 PAGES TODAY

VOL. 10, NO. 21 — HUNTSVILLE, ALABAMA, WEDNESDAY, APR. 12, 1961 — 15c PER WEEK

Man Enters Space

'So Close, Yet So Far,' Sighs Cape

U.S. Had Hoped For Own Launch

CAPE CANAVERAL, Fla. (AP) — The Redstone rocket which the United States had hoped would boost the first man into space already on a launching pad here. The Soviet Union beat its firing date by at least two weeks.

"So close, yet so far," commented a technician who is helping groom the Redstone to send one of America's astronauts on a short sub-orbital flight, hopefully late this month or early in May.

"If we hadn't had those two test fail and set the whole Little Joe shots this year, we might have made it," the technician said.

"But you have to give the Russian scientists credit. They've accomplished a remarkable breakthrough."

Dr. Hugh Dryden, deputy director of the National Aeronautics and Space Administration, told the House Space Committee in Washington Tuesday that the earliest possible date for the manned launching is about April 28.

Project Mercury officials had hoped to achieve a manned flight last December or June 1961. A series of launch mishaps necessitated additional launchings to qualify the system.

So far, 5 a space capsule failed to separate from a Little Joe rocket fired from Wallops Island, Va., in a test of the escape system.

Two weeks later, a Redstone rocket because of a faulty connection which caused the escape system to fire, blasted the capsule off on its pad. This test was to be repeated before then, the space spokesman, who said of as a short hop Jan. 31.

An engine thrust regulator stuck in the closed position, causing an excess thrust which lifted the rocket from its pad and sent it crashing back to earth. Another Redstone was aborted because of a faulty connection which caused the engine to cut off a few seconds after launch.

Another attempt to launch a Redstone with a chimp aboard failed March 24 when a report of the last minute countdown was not received in time to launch the missile. Officials said the launching was aborted because of a faulty radio transmitter, and not because of any difficulty with the rocket or the chimp.

Both the chimp and the Redstone rocket are now at Cape Canaveral, Fla., from Eglin AFB, Fla., from which the chimp was launched on his successful flight.

Hobbs Admits 1944 Slaying

By BOB WARD
Of The Times Staff

Allen B. Hobbs confessed today to the brutal murder in 1944 of Mrs. Margaret Thornton Fleming, Circuit Solicitor Marvin L. Wood said.

Hobbs, now 41, is held by Air Force authorities at Eglin Air Force Base, Fla. He signed a statement there detailing his knife-slaying of the prominent Decatur woman, Wood said.

The suspect, who has undergone psychiatric treatment by military authorities since Feb. 7, reportedly has confessed to Lt. Col. Spencer von Lind, Psychiatrist, Wood said. Hobbs reportedly was called from "hysteria" rather than from any medical cause.

Hobbs, who attended school at Decatur and Athens, is married and was then employed as a truck driver for the Coca-Cola Bottling Co. here. He was stationed at Eglin AFB, Fla., from Feb. 1, 1954, to March 28, 1956, when he was discharged from the Army Air Corps as an airman first class, Wood said.

Hobbs had been under military guard since he confessed to the slaying, Wood said. He was taken from Eglin to Montgomery, Ala., and arrived in Decatur at 10:30 a.m. today.

Hobbs was arraigned before Recorder's Court Judge Ben Hardin at 11 a.m. today on a charge of murder in the first degree. Judge Hardin ordered him held without bond in the Morgan County Jail.

Hobbs was arrested March 28 when a report of the last minute countdown was not received in time to launch the missile. Officials said the launching was aborted because of a faulty radio transmitter, and not because of any difficulty with the rocket or the chimp.

By SETH S. ANDREW
Chicago Daily News Foreign Service

The mysterious Russian space shot that carried Maj. Yuri A. Gagarin into orbit around the earth and back safely to Soviet soil has been followed by a new Soviet announcement that the first man in space is a married father of two children.

Maj. Gagarin, 27, is a native of Klushino, a village in the Smolensk region of Russia, 150 miles west of Moscow, the Soviet announcement said.

His wife, Valentina, is a textile worker and they have a daughter, Yelena, 2, and a son, Grigori, 1.

Maj. Gagarin was described as a "worker" who "stands by his story" that the flight was made entirely without human control.

Gagarin's flight was announced by Moscow radio and Tass, the official Soviet news agency, after the Soviet Union had kept the world in suspense for more than an hour and a half.

Gagarin was launched into space at 9:07 a.m. Moscow time (1:07 a.m. EST) and landed at 10:55 a.m. (3:55 a.m. EST), Tass said.

Tass said Gagarin was in "good health and spirits" after his flight.

Tass said Gagarin "was the first to burst into cosmic space and open the road to space flights for all mankind."

Tass said Gagarin's flight was made at an average speed of 17,400 miles an hour.

Tass said Gagarin's spaceship, Vostok, weighed 10,400 pounds.

Tass said Gagarin made one revolution around the earth in 89.1 minutes.

Tass said Gagarin's spaceship reached a maximum altitude of 188 miles.

Tass said Gagarin's spaceship was launched from the southern part of the Soviet Union.

Tass said Gagarin's spaceship landed in the Saratov region of the Soviet Union

Kennedy, however, will not live to see the outcome of his challenge. He will be assassinated in Dallas, Texas, two years later, on November 22, 1963.

Meanwhile the Russians march on relentlessly. Before America manages to achieve a single human orbital flight, Gherman Titov repeats and extends Gagarin's mission, performing seventeen Earth orbits in early August 1961 aboard Vostok 2.

Gus Grissom performs another suborbital flight on July 21, 1961, and finally, on February 20, 1962, nearly one year after the Russians, John Glenn becomes the first American to orbit the Earth aboard the Friendship 7 spacecraft.

But the Soviet Union ups the ante: in August, two spacecraft (Vostoks 3 and 4) fly simultaneously and cosmonauts Nikolayev and Popovich are briefly less than 5 km (3 miles) apart. The double flight is not a rendezvous, but that's how Soviet propaganda presents it. Nikolayev also sets a new endurance record: four days in space. His picture is broadcast by onboard television cameras to Russian viewers.

In June 1963, Valentina Tereshkova becomes the first woman in space, aboard Vostok 6. She is also the first civilian spacefarer, since all previous astronauts and cosmonauts have been members of the US or Soviet military.



Figure 1.4-2. Alexei Leonov during history's first spacewalk. Credit: FAI.

On its own, her 48-orbit flight lasts longer than the combined times of all the American astronauts that have flown until then. No other woman will fly in space for the next 19 years: the second woman to do so will be Russian cosmonaut Svetlana Savitskaya in 1982, aboard Soyuz T-7, and the first American woman in space will be Sally Ride in 1983, aboard Space Shuttle Challenger (STS-7).



Figure 1.4-3. Partial footage of Leonov's spacewalk. Credit: Roscosmos [http://tiny.cc/cd4bbz].

On October 12, 1964, the Soviet Union accomplishes the first multicrewed spaceflight: Voskhod 1 carries into orbit three men before the US is able to fly even two. The flight is essentially a propaganda stunt: in order to cram three astronauts into a vehicle designed for two, they are recklessly required to fly without spacesuits.

The first spacewalk is also a Russian record, set on March 18, 1965 by Alexei Leonov aboard Voskhod 2. All the US can do is send the first successful probe to Mars (Mariner 4).

The first soft landing of a space probe and the first pictures from the surface of the Moon are also a Soviet achievement, with Luna 9 in February 1966.

In the meantime, however, the US space program has been acquiring experience with human spaceflight and with the techniques required for a crewed Moon landing. Between 1965 and 1966, the spacecraft of the Gemini program carry two-man crews that achieve orbit changes, long-duration flights (up to 14 days), spacewalks and rendezvous with dockings and set a new altitude record for human spaceflight: during the Gemini 11 mission (September 12-15, 1966), Charles "Pete" Conrad and Richard F. Gordon fly to a distance of 1374 kilometers (854 miles) from the Earth's surface and become the first human beings to see their home planet as a sphere.



Figure 1.4-4. The Gemini 7 spacecraft, photographed from its sister ship Gemini 6. NASA photo KSC-65PC-171.



Figure 1.4-5. The charred Apollo 1 crew module.

Meanwhile, the Lunar Orbiter robot probes take detailed photographic surveys of the Moon's surface and the Surveyor spacecraft land on it, testing its nature and consistency. By and large, the US has caught up with the Russians.

But the Apollo program, meant to put an American on the Moon, is in deep trouble. On January 27, 1967, Gus Grissom, Ed White and Roger Chaffee die in the fire of their Apollo 1 command module during a routine test on the launch pad (Figure 1.4-5). A substantial redesign was already in progress, but the nationwide shock prompts a drastic rethinking of the ill-conceived spacecraft.

1967 is a tragic year also for Russian space endeavors. On April 24, Vladimir Komarov becomes the first person to die during spaceflight: his Soyuz 1, prepared hastily to appease the Soviet government's craving for propaganda coups, crashes fatally upon return from space.

Some researchers (such as the Italian Judica Cordiglia brothers) claim that they intercepted radio signals from other Soviet crewed flights, before and after Gagarin's mission, that ended tragically and were kept secret. The *Huntsville Times* front page shown in Figure 1.4-1 mentions (in the article *Reds Deny Spacemen Have Died*) the suspicions of brigadier general Don Flickinger, head of the medical section of the US Air Force astronaut selection and training program, in this regard, together with the Soviet denial. However, so far the cross-checks of spaceflight historians such as James Oberg and others have found no evidence to support these claims and have instead pointed out their inconsistencies.

1.5 Apollo gets up to speed



Figure 1.5-1. The cover of Time*, December 6, 1968.*

The massive US investments in space begin to bear fruit. The huge Kennedy Space Center at Cape Canaveral has risen from the Floridian swamps in record time. Several uncrewed flights test the Apollo spacecraft, the giant Saturn V Moon rocket designed by Wernher Von Braun, and the ground support hardware and staff.

Meanwhile the Soviet space program nets another first: on September 18, 1968, the Zond 5 automatic probe takes the first living beings around the Moon. Turtles, wine flies, meal worms, plants, seeds and bacteria are returned safely to Earth, apparently none the worse for the trip. What's more, the spacecraft is clearly big enough to carry a man.

On October 11, Walter Schirra, Donn Eisele and Walter Cunningham perform the first crewed flight of the redesigned Apollo spacecraft, testing Apollo 7 in Earth orbit for eleven days.

Their flight is also the first American mission with a crew of three and the first crewed test of the Saturn IB rocket, Saturn V's smaller sibling. There's no time to waste: the US government knows that the Soviets are secretly getting ready to beat America to the Moon.

So two months later, Apollo 8 is the first crewed flight of a Saturn V, and although the giant booster has only flown twice previously the goal is already tremendously bold: to travel three hundred times farther than anyone has ever done and take three American astronauts around the Moon.

On December 24, 1968, for the first time in history, human beings see the Moon with their own eyes from as little as 110 kilometers (69 miles) and fly over its far side, which is forever hidden from view from Earth.

The worldwide emotional impact of this mission is huge, not least because it is shown live on TV. Much of mankind is able to share the view of the cratered surface of the Moon rolling past as astronauts Frank Borman, James Lovell and William Anders read verses from the Book of Genesis. The Christmas Eve broadcast from the Moon is the most watched TV event up to that time.

The Apollo 8 astronauts also take unforgettable photographs of their destination and of our home planet as a distant, delicate blue marble suspended in the blackness of the cosmos. The contrast with the harsh, lifeless lunar horizon could not be more eloquent and striking in its message to mankind.

At least in the eyes of public opinion, the flight is an unmitigated American triumph that marks the defeat of the Soviet space propaganda machine. Little is said, at the time, about the disastrous conditions aboard the spacecraft: vomiting and diarrhea caused by space sickness, outgassing of sealant that fogged up the windows and hindered star sighting for navigation, water pooling dangerously in the crew cabin, and more.

But the race to the Moon isn't over yet. The actual landing is yet to be achieved, and the Soviet Union secretly hasn't given up on its ambitions to be the first to land a human being on the Moon.



Figure 1.5-2. The Earth seen from the Moon by the Apollo 8 astronauts. NASA photograph AS8-14-2383.

1.6 The real conspiracy: secret Soviet moonshots

The Soviet Union has secretly been developing the N1-L3 system, designed by Sergei Korolev: a giant rocket, the N1, as big as a Saturn V and capable of sending two cosmonauts towards the Moon in a vehicle, known as L3, that includes a lunar lander designed to carry one Russian to the surface of the Moon.



Figure 1.6-1. Preparing the N1 rocket.

The N1, however, is underfunded and plagued by personal rivalries among top Soviet rocket engineers (so much that there is also a parallel development program for another giant Soviet rocket, the UR-700, championed by Vladimir Chelomei). The thirty engines of the N1's first stage are a nightmare to coordinate and control. The Soviet military oppose the project because they see it as an expensive propaganda gimmick with no practical military use, differently from all of Russia's previous space rockets, which were derived from nuclear weapon-carrying missiles.

The giant booster flies for the first time in February 1969 for an uncrewed test and explodes 66 seconds after liftoff. The failure is kept secret, and in May the Soviet Union officially states that it does not intend to send cosmonauts to the Moon because it will not risk human lives in such an endeavor and will use only robot probes instead.

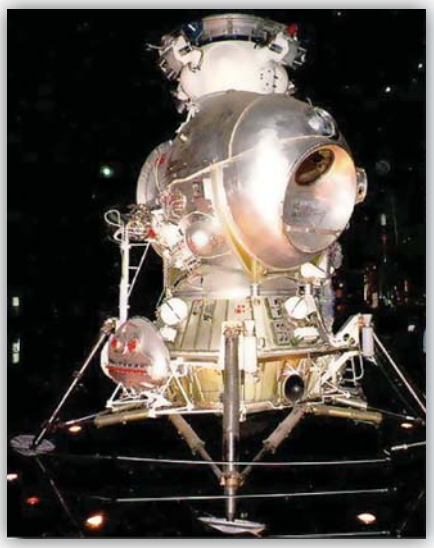


Figure 1.6-2. The Soviet lunar landing vehicle (Lunniy Korabl).

The second launch is an even worse disaster. On July 3, 1969, days before the American Moon landing, an uncrewed N1 falls back onto the launch pad moments after ignition. The explosion of its 2,600 tons of fuel is the most violent in the history of rocketry. This failure, too, is silenced. Only unconfirmed rumors of a Soviet disaster reach the West.

Officially, for the Soviet Union the N1-L3 project never existed. It will continue in total secrecy for a few more years, testing the lunar lander in Earth orbit, but after two more disastrous launch failures the N1 will be abandoned.



Figure 1.6-3. Left to right: The Soviet and US lunar landing vehicles to scale. Credit: Nick Stevens, Nick-stevens.com.

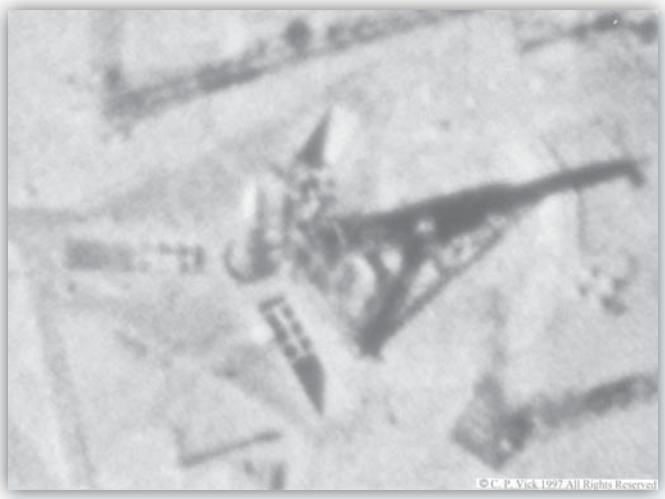


Figure 1.6-4. An N1 rocket on its launch pad, caught by a KH-4 Corona spy satellite. Credit: C. P. Vick.

No Soviet cosmonaut will ever walk on the Moon.

None of this will be known to the public for more than twenty years, but the US government is well aware of the Soviet attempt thanks to spy satellite photographs of the massive rocket and of its launch facilities at the Baikonur Cosmodrome. Other pictures also reveal the devastation of the pad after the second launch failure of the N1.

The US government, in other words, knows that Russia is out of the Moon race, but can't tell the public, because this would reveal the capabilities of its spy satellites and the political grounds for the Moon shots would vanish.

Secretly, there's no more rush to get to the Moon, but there's still a murdered president's pledge to be kept, and for public opinion, unaware of the N1 disasters, the race is still on.

Further details of the Soviet Moon plans are in Chapter 7.

1.7 Dress rehearsals, then the real thing

Kennedy's deadline is looming and the Apollo project advances at full speed. In March 1969, Apollo 9 flies in Earth orbit to test the lunar module, the navigation systems, the lunar spacesuits and the docking maneuvers.

In May, Apollo 10 soars to the Moon and rehearses every step of a Moon landing mission except for the touchdown itself. Apollo 10's lunar module carries Thomas Stafford and Gene Cernan to within 14.45 kilometers (47,400 feet) of the lunar surface.

The next mission, Apollo 11, takes mankind to the Moon, live on worldwide TV, landing there on July 20, 1969. Commander Neil Armstrong cautiously sets his left foot on the surface of the Moon at 10:56 EDT (July 21 2:56 UTC).

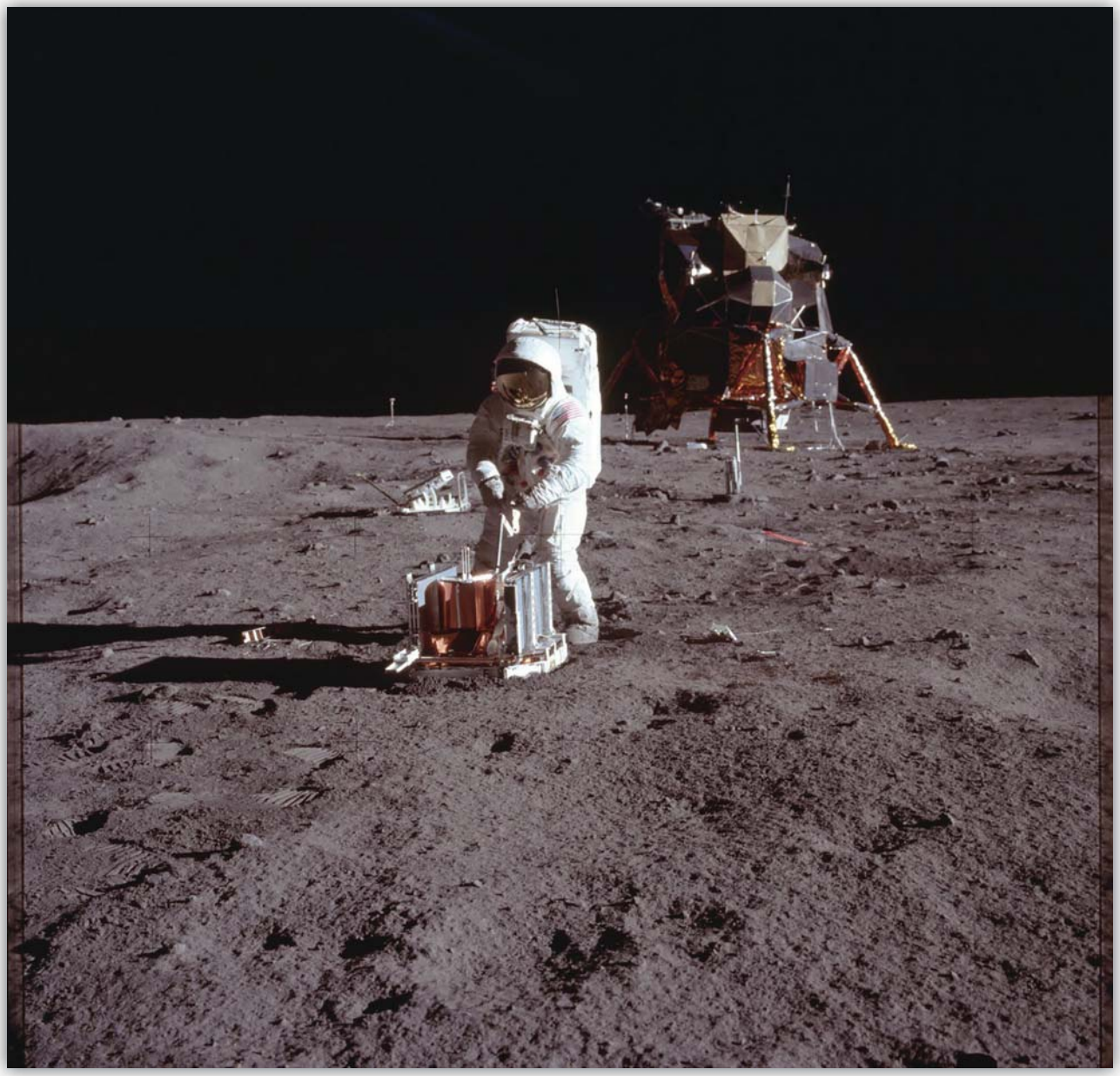


Figure 1.7-1. Buzz Aldrin on the Moon, photographed by Neil Armstrong. NASA photo AS11-40-5946.



Figure 1.7-2. The Apollo 11 crew: Neil Armstrong, Michael Collins and Buzz Aldrin. Official NASA portrait, March 1969.

Lunar Module Pilot Edwin "Buzz" Aldrin then joins him and together they plant the flag of the United States on the surface, conduct scientific experiments, collect Moon rock samples and take historic photographs while the third crew member, Command Module Pilot Michael Collins, waits in lunar orbit to take them home and join them in the history books.

The Soviets make one last attempt to steal the show by trying to retrieve a lunar soil sample with the Luna 15 uncrewed probe just before the American astronauts return home. But Luna 15 crashes on the Moon while Armstrong, Aldrin and Collins are getting ready to return with 21.5 kilograms (47.5 pounds) of Moon rocks. The Luna 1969B and 1969C missions, in April and June 1969, may also have been failed attempts to retrieve lunar soil samples (*Tentatively Identified Missions and Launch Failures*, Nasa.gov, 2005).

Between 1969 and 1972, the United States lands astronauts on the Moon six times, with increasingly advanced, extended and complex missions. Apollo 11, 12, 14, 15, 16 and 17 carry twelve men to the surface of the Moon and return over 382 kilograms (842 pounds) of carefully selected lunar rocks and a wealth of scientific data that is still being used and analyzed today.

Apollo 13, too, is planned as a lunar landing mission but has to be aborted due to an oxygen tank rupture on the way to the Moon. The crewmembers (James Lovell, John "Jack" Swigert and Fred Haise) narrowly escape death, brilliantly aided by their skills and by the resourcefulness of Mission Control on Earth. Their space Odyssey captures the world's attention, highlighting the perils of space travel that the success of previous missions had caused many to underestimate.



Figure 1.7-3. Aldrin, Armstrong and Collins in 2009, during a visit to the Smithsonian.

The Apollo project was originally scheduled to end with Apollo 20, but political issues and the Apollo 13 near-disaster led to the gradual cancellation of the last three planned missions when their vehicles had already been built.

Since December 14, 1972, when geologist Harrison Schmitt and Commander Eugene Cernan climbed back up the ladder of Apollo 17's lunar module and closed the hatch behind them after three days of lunar surface exploration, no human being has set foot on the Moon.

1.8 Post-Apollo explorations

After the Apollo missions, the Moon has been visited by many other uncrewed spacecraft of various countries.

Between 1970 and 1976, Soviet automatic probes of the Luna series landed on the Moon, brought back small rock samples and traveled extensively over its surface with remotely controlled Lunakhod rovers, analyzing its soil and transmitting thousands of pictures.

Apart from the Soviet Union, the United States and China, no other country so far has achieved a soft landing of a crewed or uncrewed vehicle on the Moon. However, Japan, the US, Europe, China and India have explored the Moon in detail from lunar orbit, and are still doing so, with probes such as Muses-A, Clementine, Lunar Prospector, Smart 1, Selene/Kaguya, Chang'e, Chandrayaan and Lunar Reconnaissance Orbiter.

Japan, India and the US have also crashed space probes intentionally into the Moon (Selene/Kaguya, Chandrayaan, LCROSS), creating artificial craters and generating debris clouds that have allowed remote analysis of the surface of the Moon. In 2013 China achieved the first soft landing on the Moon by any spacecraft in 37 years when its Chang'e 3 lander, carrying the Yutu rover, touched down in the Moon's Bay of Rainbows (*Sinus Iridum*); in 2019 it performed the first soft landing on the far side of the Moon, with the Chang'e 4 probe and Yutu 2 rover.

Thanks to the vast amount of science data gathered by these probes, today we have an extremely detailed altimetric map of the entire lunar surface and know its geology in detail. For example, their ongoing work has allowed scientists to confirm the presence of water on the Moon.

The exploration of our satellite continues: several national and private missions with robotic landers and rovers are planned for the near future. However, there are no solid plans for crewed trips back to the Moon, except for the United States' *Artemis* program, which is tentatively scheduled to land a crew on the Moon by 2024.

In the decades after Apollo, human presence in space has been frequent, with Russian, American and Chinese flights which also carried astronauts from many other countries and used advanced vehicles such as the US Space Shuttle.

Shifting from competition to cooperation, Russia, the United States, Canada, Europe and Japan have carried out joint missions and built the International Space Station, which has now been inhabited uninterruptedly since 2000 and orbits the Earth at an altitude of approximately 400 km (250

miles). All these missions, however, have remained very close to Earth: nobody has ventured as far as the Apollo lunar crews.

The six Moon landings were seen at the time as a prelude to ongoing, ever-expanding crewed space exploration, but today they appear to be destined for many more years to remain unrivaled adventures, extraordinary leaps forward whose early promise was later abandoned.

2 How we went to the Moon

Understanding the claims of Moon hoax theorists and the reasons why they're wrong requires at least a smattering of knowledge of the jargon, technology and stages of an Apollo moonshot. This chapter is mostly based on the Apollo 11 mission, the first Moon landing, but the basic concepts presented here apply to all the lunar flights.

2.1 The Saturn V rocket

The Saturn V-Apollo stack stood 111 meters (363 feet) tall and weighed almost 3,000 tons (6.5 million pounds). Even today it is still the most powerful operational rocket ever built; only the failed Soviet N1 exceeded it in terms of total thrust.



Figure 2.1-1. Apollo 11's Saturn V on the launch pad. Detail of NASA photo S69-38660.

The Saturn V consisted of three stages, topped by the Apollo spacecraft, which carried three astronauts. The very tip of this stack was the Launch Escape System, a high-acceleration rocket designed to whisk the crew compartment with the astronauts to safety in case of an emergency during liftoff.

The first stage, known as S-IC and manufactured by Boeing, was 42 meters (138 feet) tall, had a diameter of 10 meters (33 feet) and was equipped with five enormous F-1 engines that gulped 13.3 tons (29,300 pounds) of kerosene and liquid oxygen *per second* at liftoff, lifting the entire rocket to an altitude of about 67 kilometers (220,000 feet) and accelerating it to a speed of approximately 9,900 km/h (6,180 mph) in a little over two and a half minutes. The spent S-IC stage was then jettisoned and fell into the Atlantic Ocean.

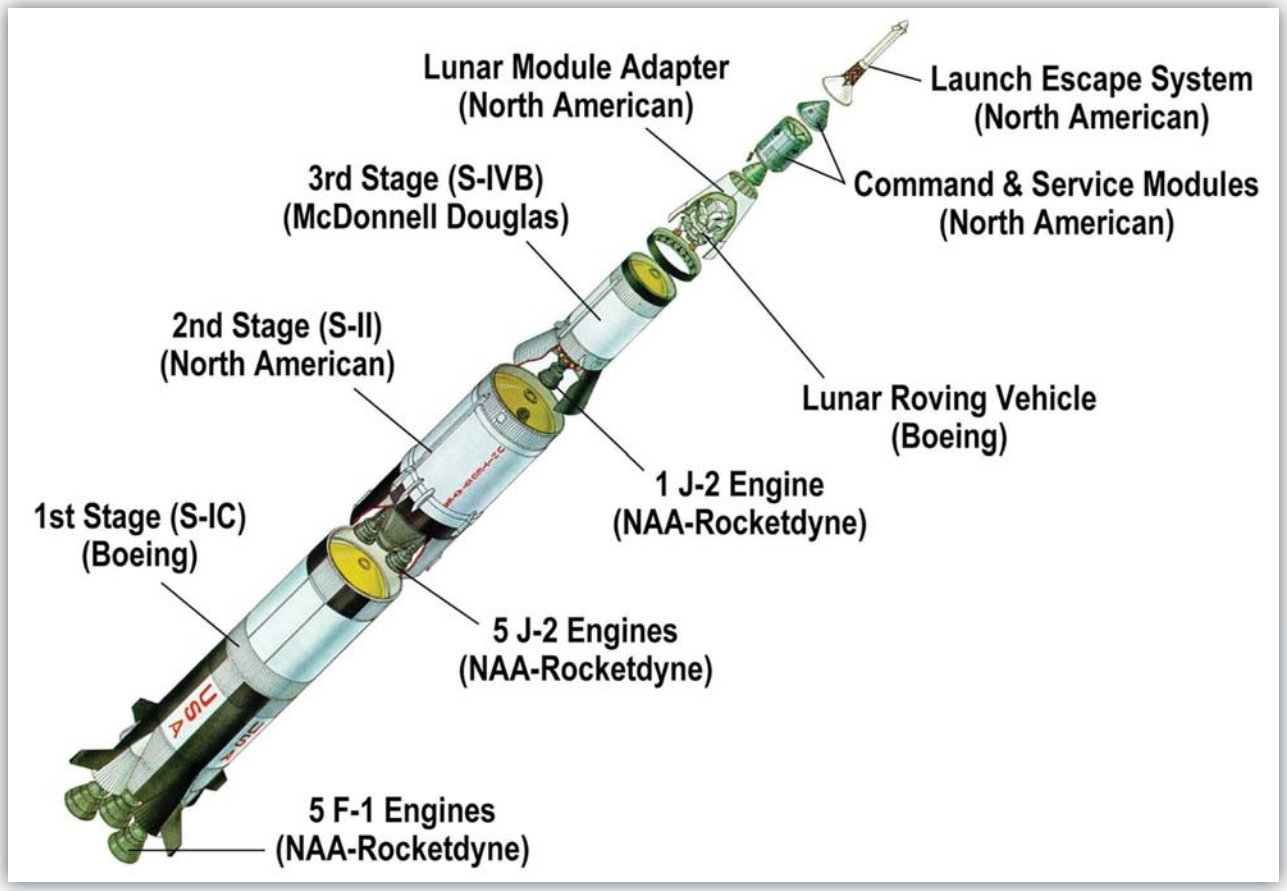
The S-II second stage used liquid hydrogen and oxygen to fuel its five J-2 engines and continue the climb to space, reaching a speed of almost 24,000 km/h (14,800 mph) and an altitude of approximately

182 kilometers (600,000 feet) nine minutes after liftoff. It was then jettisoned like the previous stage. Together, these two stages constituted nine tenths of the total weight of a Saturn V.

To reach the speed of 28,000 km/h (17,400 mph) required to orbit the Earth at an altitude of 190 kilometers (617,000 feet), the Saturn V needed the extra kick of its third stage, the S-IVB, which had a single restartable J-2 engine.

Less than twelve minutes after launch, the astronauts were already in a parking orbit around the Earth, where they checked the onboard systems. The spacecraft at this point had the configuration shown in Figure 2.1-3.

After one orbit and a half, two hours and forty-four minutes after liftoff from Florida, the third-stage engine was restarted and burned for almost six minutes, accelerating the spacecraft to 39,000 km/h (24,200 mph) towards the Moon, which was approximately 400,000 kilometers (250,000 miles) away (the Earth-Moon distance varies every 27.3 days from 363,100 to 405,700 kilometers (225,600 to 252,000 miles), measured center to center). The spacecraft then began coasting with its engines off towards its destination, gradually slowing down due to the Earth's gravitational attraction and then accelerating again as it approached the Moon.



Above: Figure 2.1-2. The Saturn V-Apollo stack components. Credit: Boeing Space, 2018.

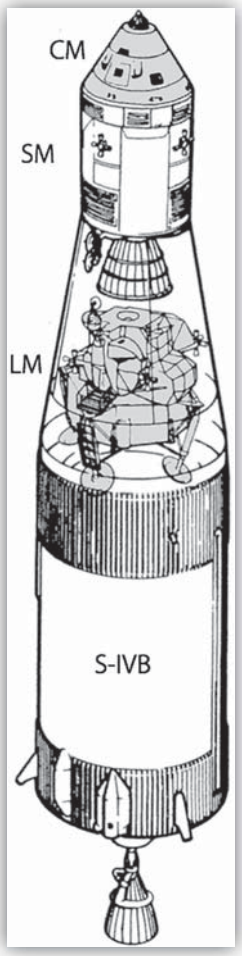


Figure 2.1-3. From the top: Command Module, Service Module, Lunar Module and S-IVB stage. Source: Apollo 11 Press Kit (enhanced to highlight the LM and CM).

During their three-day trip, the astronauts, aided by the onboard computers and by the observations and measurements performed on Earth, carried out slight course corrections and a very delicate undocking, rotation and docking maneuver to prepare the Apollo spacecraft for its lunar mission and abandon the third stage of the Saturn V.

2.2 The Apollo spacecraft

The three crewmembers traveled in the cone-shaped Command Module (CM), which was 4 meters (13 feet) wide at the base and 3.5 meters (11.5 feet) tall, with a total cabin volume roughly equal to the cargo body of a small van.

There's no toilet: bags were used for solids, while liquids were dumped overboard through a tube.

The CM had small maneuvering thrusters, a heat shield to protect it from the heat of reentry, and three parachutes, as it was the only part of the giant rocket that returned to Earth.

Behind the astronauts there was the cylindrical Service Module (SM), which held the fuel for the main rocket engine of the Apollo spacecraft and for the sixteen maneuvering rockets (arranged in four cross-like clusters of four) and most of the oxygen, water, electric power and communication systems required for the mission.



Figure 2.2-1. The Apollo Command Module (left) and Service Module (right). Credit: DavidTeixidor.

A conical aerodynamic fairing connected the command and service modules to the third stage of the Saturn rocket (S-IVB) and enclosed the Lunar Module (LM), the spider-like spacecraft that would be used by two of the three astronauts to land on the Moon while the third waited for them in the Command Module.



Figure 2.2-2. The cramped interior of the Apollo Command Module used for the Apollo-Soyuz mission: left to right, Donald K. Slayton, Vance D. Brand and Thomas P. Stafford. NASA photo S75-22747.

Since the Lunar Module was to be used only in the

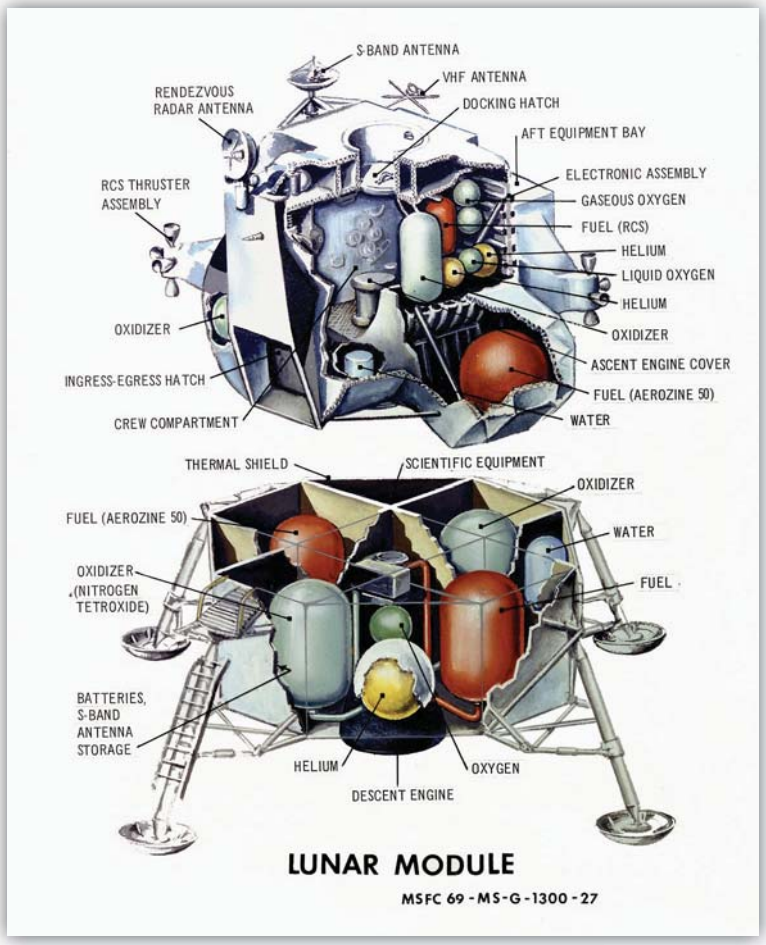


Figure 2.2-3. Cutout drawing of the Lunar Module. NASA document MSFC69-MS-G-1300-27 (Apollo 10 Press Kit*).*

vacuum of space, it didn't need to be streamlined and instead had to be as light as possible in order to reduce the fuel requirements and maximize its payload. Accordingly, it was stripped down to the absolute minimum: even the seats were sacrificed, so the astronauts flew the LM while standing.

The LM was 7.3 meters (23 feet) tall, weighed approximately 15 tons (33,000 lb) and was divided into two stages, shown separately in Figure 2.2-3.

The *descent stage* was the lower octagonal part, which had a single engine to brake the descent to the Moon, four shock-absorbing landing legs and storage compartments for scientific equipment, water, fuel and (from Apollo 15 onwards) an electric Moon buggy (the Lunar Roving Vehicle).

The top part of the Lunar Module, known as *ascent stage*, contained the cramped crew cabin, some oxygen, food and water supplies, the onboard computers, the radio and television equipment and the single rocket engine used to climb back to orbit from the Moon. The ascent stage was equipped with sixteen attitude control thrusters (in four clusters of four, as in the Service Module) with their propellant tanks.



Figure 2.2-4. An unused LM at Washington's National Air and Space Museum. Credit: Wikipedia.

The astronauts viewed the lunar surface during landing through two small sloping triangular windows at the front of the ascent stage. After touchdown, they exited the vehicle by crawling backwards in their bulky spacesuits through a narrow square hatch and then climbed down along a ladder attached to one of the legs of the descent stage, as shown by the LM on display at the National Air and Space Museum in Washington, D.C. They then began their exploration of the Moon.

At the end of their stay on the Moon, the astronauts lifted off in the ascent stage, using the descent stage as a launch pad. The descent stage was left on the Moon.

2.3 Crucial maneuvers

Success of the mission and survival of the astronauts depended on some very tricky undocking and redocking maneuvers during the outbound journey and on a vital rendezvous to be achieved while in orbit around the Moon.

A few hours after liftoff, the crew separated the Command and Service modules (CSM) from the rest of the spacecraft and positioned them slightly ahead by using the SM's maneuvering thrusters. The four panels of the fairing were released, exposing the lunar module. The astronauts then turned the CSM around, docked with the LM and extracted it from the S-IVB, the third stage of the Saturn V rocket.



Figure 2.3-1. Extraction of the Lunar Module. Animation by Michael Quinn [http://tiny.cc/w8glbz].

The CSM and the LM then continued their flight towards lunar orbit, while the S-IVB rocket motor was restarted to nudge the spent stage away into an orbit around the Sun or, from Apollo 13 onwards, to crash into the Moon and produce a man-made moonquake, which was picked up by the seismometers placed on the lunar surface by previous missions, allowing scientists to probe the interior structure of the Moon.

The docked Lunar Module was linked to the CSM by a tunnel, through which the astronauts crawled to power up and check the vehicle and prepare it for descent to the Moon. As the spacecraft approached the Moon, the drag of Earth's gravity that had been gradually slowing it began to fade and Apollo's speed started to increase due to the pull of lunar gravity.

The astronauts turned the spacecraft around so that the Service Module's powerful main engine was pointing forward. They had to achieve multiple carefully timed burns of this engine, as they swung repeatedly around the far side of the Moon, out of radio contact with Earth, in order to slow down and gradually achieve a stable, almost circular orbit around their destination, at an altitude of 100 to 120 kilometers (54 to 65 nautical miles) and a speed of approximately 5,900 km/h (3,700 mph).

The two astronauts that would walk on the Moon transferred into the lunar module, while their colleague stayed in the Command Module, and the two vehicles undocked (in the more advanced lunar landing missions, the CSM carried the LM closer to the Moon before undocking, in order to conserve the lander's limited fuel). After flying in formation to visually inspect each other and run a final check of all onboard

systems, the LM pointed its descent engine forward and fired it to begin the landing phase.

On the Moon there's no atmosphere to glide through with wings or parachutes, so descent depended entirely on the flawless operation of the descent stage's single rocket engine, which had to reduce the spacecraft's speed from 5,900 km/h (3,700 mph) to zero in about twelve minutes and then allow the LM to hover just above the lunar surface long enough to find a safe landing spot. Fuel reserves were tight and left little margin for error and none for second attempts.

After landing, the astronauts performed one or more moonwalks (*Extravehicular Activities* or *EVAs*) to gather science data and samples under the watchful eye of a



Figure 2.3-2. Buzz Aldrin on the Moon during the Apollo 11 EVA. NASA photo AS11-40-5872.

television camera that broadcast their activities live to Mission Control and to a worldwide audience back on Earth.

The Apollo moonwalkers had fully autonomous spacesuits, with oxygen, cooling systems and radio links in their backpacks. In the more advanced missions, they also used an electric car, the *Lunar Roving Vehicle* or *Rover*, to cover distances of as much as 35 kilometers (22 miles) during Apollo 17, the lunar mission which also set the total EVA duration record, with over 22 hours spent outside the Lunar Module during three moonwalks.

Once their lunar excursion was complete, the astronauts threw out all unnecessary weights and lifted off in the ascent stage of the LM. The timing and execution of this liftoff had to be very accurate in order to rendezvous with the Command and Service Module, in which the third crewmember was waiting for them in lunar orbit.

If the single ascent engine failed to fire, the lunar astronauts would be trapped on the Moon, with no chance of rescue. With narrow margins for error, if the engine didn't fire at the right time, with the right thrust and for the right duration, or if the trajectory was incorrect, they would not achieve the rendezvous and would perish in orbit or crash back onto

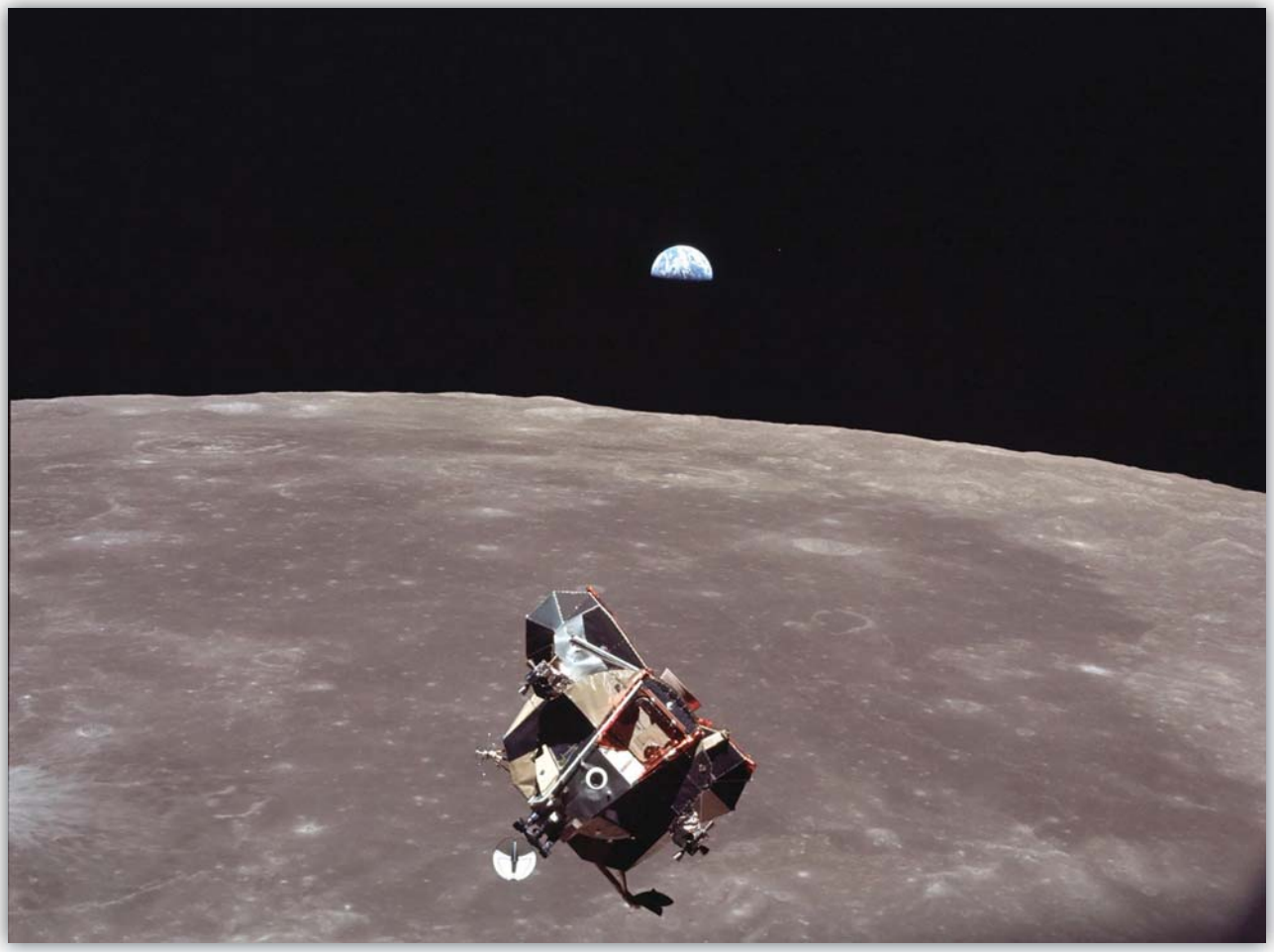


Figure 2.3-3. The Apollo 11 LM climbs back from the Moon. NASA photo AS11-44-6643 (cropped).

the Moon. The third astronaut would have no choice but to abandon them and return to Earth alone.

The final rendezvous between the Command Module and the ascent stage of the Lunar Module required docking the two spacecraft so that the moonwalkers could return to the Command Module with their priceless cargo of science data, Moon rocks, photographs and film footage.

The ascent stage of the LM was then jettisoned, subsequently crashing onto the Moon, while the instruments placed by the astronauts on the lunar surface radioed their data to scientists back on Earth.

The astronauts then rested, checked all the spacecraft's systems, and fired the Service Module's main engine again to accelerate and leave lunar orbit, heading home to Earth. The return journey took approximately three days.

2.4 Fiery return

Shortly before contact with the Earth's atmosphere, the Service Module, too, was jettisoned. Of the 111-meter (363-foot) behemoth that had left Earth a few days earlier, only the small conical Command Module remained. It hurtled into the Earth's atmosphere at about 38,000 km/h (23,600 mph) with no braking rockets.

Air resistance slowed the spacecraft but also generated tremendous heat. Its heat shield had to cope with temperatures up to 2,700°C (5,000°F), and reentry had to occur at a very precise angle, between 5.5 and 7.5 degrees.

If the reentry angle was too shallow, the CM would slice through the thin upper layers of the atmosphere without losing enough speed and would end up in space again, with no chance of safe return. An excessively steep angle would overload the heat shield, turning the spacecraft and its occupants into a deadly fireball.

The astronauts also had to deal with violent deceleration (up to 7 g, which is equivalent to having seven times one's own

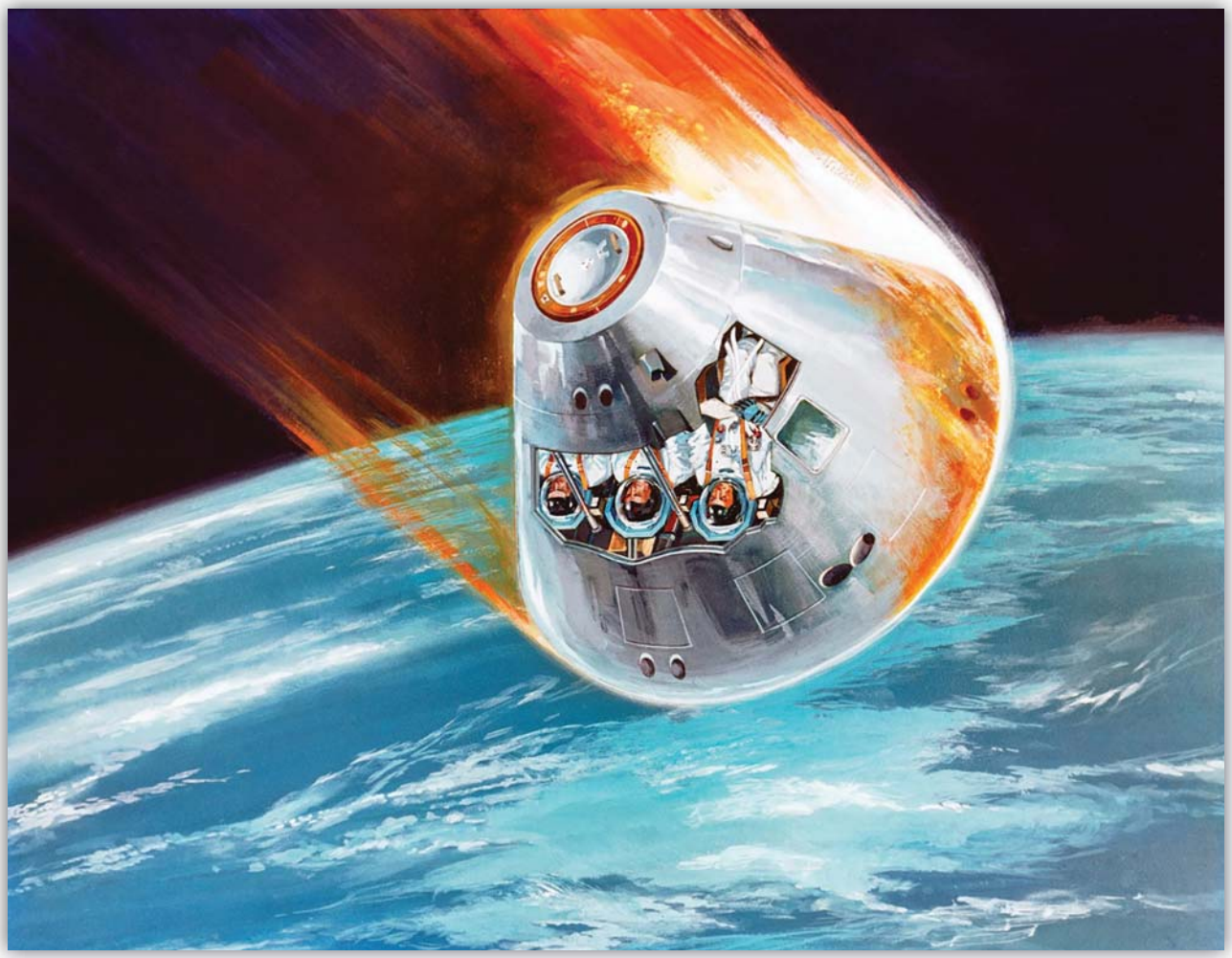


Figure 2.4-1. Artist's illustration of the reentry of an Apollo Command Module, shown partially cutout. NASA image S68-41156 (1968).

weight). The heat of high-speed reentry also produced a wall of ionized air, which blocked radio communications. The people in Mission Control, who had guided and supported the entire flight with their vast technical skills and resources, had no way to know the outcome of reentry until the spacecraft slowed sufficiently to resume radio contact. Small drogue parachutes opened at an altitude of 7,000 meters (23,000 feet), followed by the main chutes at 3,000 meters (10,000 feet).

The Apollo capsule splashed down in the Pacific Ocean, where it was reached by a recovery helicopter, which hoisted up the astronauts on a winch with the aid of frogmen and then flew the returning spacefarers to a nearby aircraft carrier. Another chopper later recovered the spacecraft and its precious science cargo.



Figure 2.4-2. Splashdown of Apollo 16. NASA photo AP16-S72-36293.

At the end of the early Moon landing missions, the astronauts donned airtight suits when they exited the Apollo spacecraft and were then quarantined in sealed quarters to guard against the remote chance of Moon germs. From Apollo 15 onwards, this precaution was dropped and the astronauts were free to join the celebrations for their safe return from a fantastic voyage.

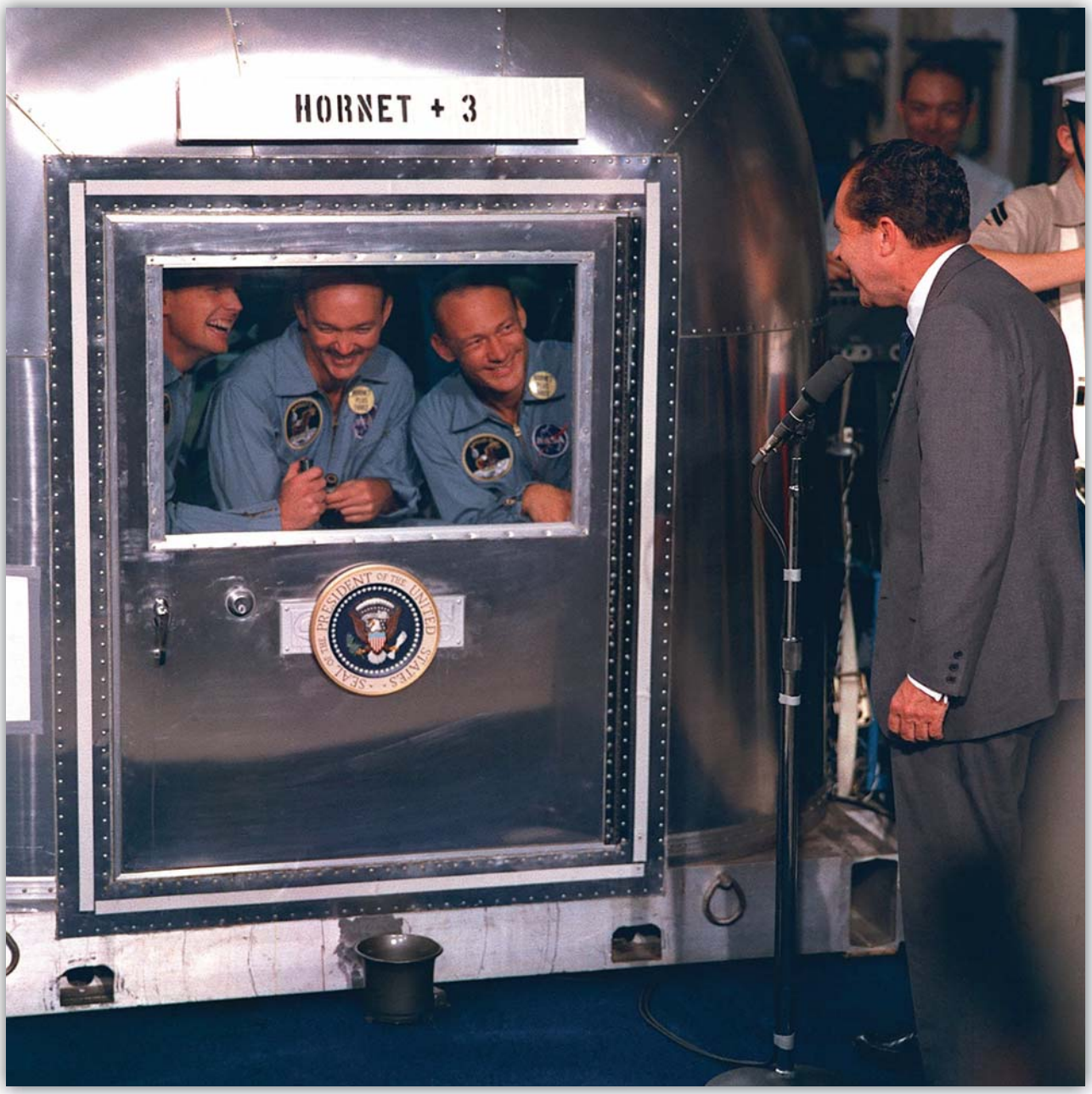


Figure 2.4-3. Armstrong, Collins and Aldrin with US President Richard Nixon during the astronauts' quarantine.

2.5 The true cost of Apollo

The crewed Moon landings did not come cheap. In 1973, the total cost of the Apollo program was reported as 25.4 billion dollars over a ten-year period. In 2004, the Congressional Budget Office estimated this cost to be equivalent to roughly 170 billion in 2005 dollars [*House Subcommittee on Manned Space Flight of the Committee on Science and Astronautics*, *1974 NASA Authorization, Hearings on H.R. 4567, 93/2, Part 2*, page 1271; *A Budgetary Analysis of NASA's New Vision for Space, Congressional Budget Office*, September 2004].

The Apollo project was widely perceived as an unsustainable and exorbitantly costly endeavor, despite the fact that the money was all spent on Earth and helped to train a whole generation of scientists and engineers and to develop countless technologies that we still use today. This misperception contributed to the early cancellation of the project once its primary political goal had been achieved.

Through the years, the cost of Apollo and of space ventures in general has been consistently and greatly overestimated by American public opinion. For example, a 1997 poll reported that Americans believed on average that NASA drained 20% of the entire US budget, although the actual figure has always been less than 1%, with the exception of the Apollo era, when it peaked at 2.2% in 1966 [*Public Opinion Polls and Perceptions of US Human Spaceflight,* Roger D. Launius (2003); *The Manhattan Project, Apollo Program, and Federal Energy Technology R&D Programs: A Comparative Analysis,* Deborah D. Stine (2009)].

By way of comparison, in 2005 the total expenditure for US defense was 493.6 billion dollars, social security outlays were 518.7 billion and Medicare/Medicaid outlays totaled 513 billion, according to the Congressional Budget Office. In other words, in recent years the US spent on defense *each year* three times the cost of the entire Apollo program.

Looking at it another way, getting to the Moon cost each one of the 202 million Americans alive in 1969 the grand sum of 84 dollars a year for ten years (in 2005 dollars). That's roughly equivalent to twenty packets of cigarettes per year per person. In fact, two years of US consumer spending on tobacco products, which was 90 billion dollars per year according to 2006 CDC estimates, would pay for the entire Apollo project.

But in politics as in public opinion, perception often matters far more than reality.

* * *

This, in summary, is how a Moon mission was accomplished with 1960s-era technology: high costs, minimal margins for error, high chances of failure, no rescue options, with the whole world watching live on TV and a nation’s prestige at stake. No wonder nobody has gone back to the Moon since.

3 The best evidence of the Moon landings

Moon hoax supporters claim to have countless items of evidence to back their views. In a face-to-face discussion it's often impossible to debate and debunk each item, as the second part of this book will do. However, there's another, more feasible approach: provide the clearest evidence of the fact that we *did* go to the Moon.

If we have simple, clear, bulletproof evidence that we actually landed on the Moon in 1969 and went back five more times, then all the conspiracy theorists' objections and items of alleged "evidence" must be wrong. End of story. Exactly *why* they're wrong is another question, which has a very revealing answer, but at least we can start on a very firm footing.

So is there any such clear, hard evidence of the Moon landings that can be understood by a non-expert? It might seem difficult to prove something that took place over so many decades ago, on another world 400,000 kilometers (250,000 miles) away, since we can't go there and check – not yet, anyway – and most of the evidence comes from a single source, i.e., NASA, which clearly might have some interest in self-promotion.

But the answer is *yes*: there is hard, independent evidence of the Moon landings. However, it's not the kind of evidence you might expect and it provides a great opportunity to become better acquainted with many fascinating aspects of space exploration.

3.1 Documentation

The United States' crewed Moon landing program generated an immense amount of documents: technical manuals, plans and blueprints for even the tiniest spacecraft part, thousands of science articles, checklists, procedures, measurements, budgets, audits, contracts, purchase orders, inspection reports, press kits, mission reports, medical reports, experience reports, sample analyses, full transcripts of communications, and much more.

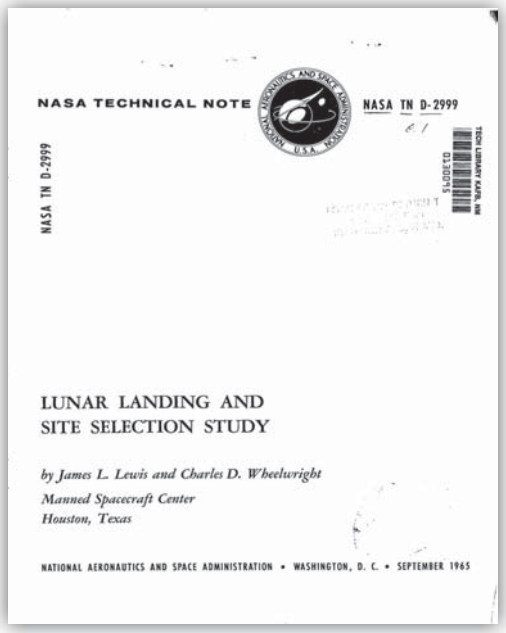
This documentation includes high-quality photographs, radio and television broadcasts, color film footage, telemetry data, and ground-to-air and onboard audio recordings.

The six Apollo Moon landings generated 6,175 photos and dozens of hours of TV recordings and movie camera

footage. That's just the amount of pictures and footage *taken on the lunar surface*, excluding the rest of the trip, which would bring the total to roughly 20,000 photographs.

All this material has been publicly available for decades to anyone who asked for it and paid for duplication costs. Today it's also available on the Internet, on digital media or on paper (see the *References* section at the end of this book). Apart from occasional typos and minor errors, it is all completely self-consistent and in agreement with the space research conducted by other countries.

These documents have been studied for decades by the world's leading researchers and are the basis for countless science and technology innovations that we use every day, from GPS navigation to mobile phones. These inventions wouldn't work if they were based on fake data.



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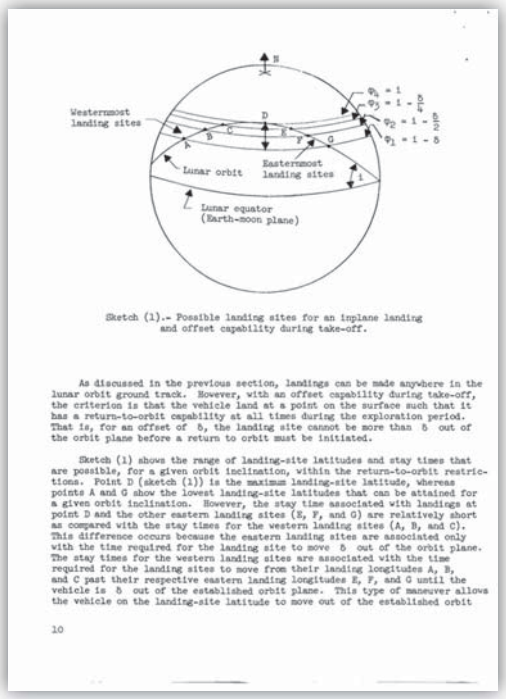
LUNAR LANDING AND
SITE SELECTION STUDY

by James L. Lewis and Charles D. Wheelwright
Manned Spacecraft Center
Houston, Texas

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • SEPTEMBER 1965

Figure 3.1-1. An example of the vast documentation of the Moon missions: a landing site selection study dated 1965.

Today NASA's reports and data can be analyzed with techniques that didn't even exist at the time and that any 1969 fakery accordingly would have been unable to preempt. *If they had been forged, the world's experts would know*. Moreover, achieving such a massive, perfectly consistent and future-proof forgery would have been probably harder than actually going to the Moon.



Sketch (1).- Possible landing sites for an inplane landing and offset capability during take-off.

As discussed in the previous section, landings can be made anywhere in the lunar orbit ground track. However, with an offset capability during take-off, the criterion is that the vehicle land at a point on the surface such that it has a return-to-orbit capability at all times during the exploration period. That is, for an offset of δ, the landing site cannot be more than δ out of the orbit plane before a return to orbit must be initiated.

Sketch (1) shows the range of landing-site latitudes and stay times that are possible, for a given orbit inclination, within the return-to-orbit restrictions. Point D (sketch (1)) is the maximum landing-site latitude, whereas points A and G show the lowest landing-site latitudes that can be attained for a given orbit inclination. However, the stay time associated with landings at point D and the other eastern landing sites (E, F, and G) are relatively short as compared with the stay times for the western landing sites (A, B, and C). This difference occurs because the eastern landing sites are associated only with the time required for the landing site to move δ out of the orbit plane. The stay times for the western landing sites are associated with the time required for the landing sites to move from their landing longitudes A, B, and C past their respective eastern landing longitudes E, F, and G until the vehicle is δ out of the established orbit plane. This type of maneuver allows the vehicle on the landing-site latitude to move out of the established orbit

10

Figure 3.1-2. Another example of the publicly available Apollo documents: an excerpt from a study on landing site locations and stay times.

Cross-checks

Rather amusingly, the most significant technical error found in decades of expert examination of the Moon landing documents is that NASA claimed incorrectly that there were no photographs of Neil Armstrong walking on the Moon and that all the photos of the historic first moonwalk of Apollo 11 showed his crew mate Buzz Aldrin. Quite an embarrassment, considering that Armstrong was the commander of the mission and the first man to set foot on the Moon's surface (Aldrin joined him a few minutes later).

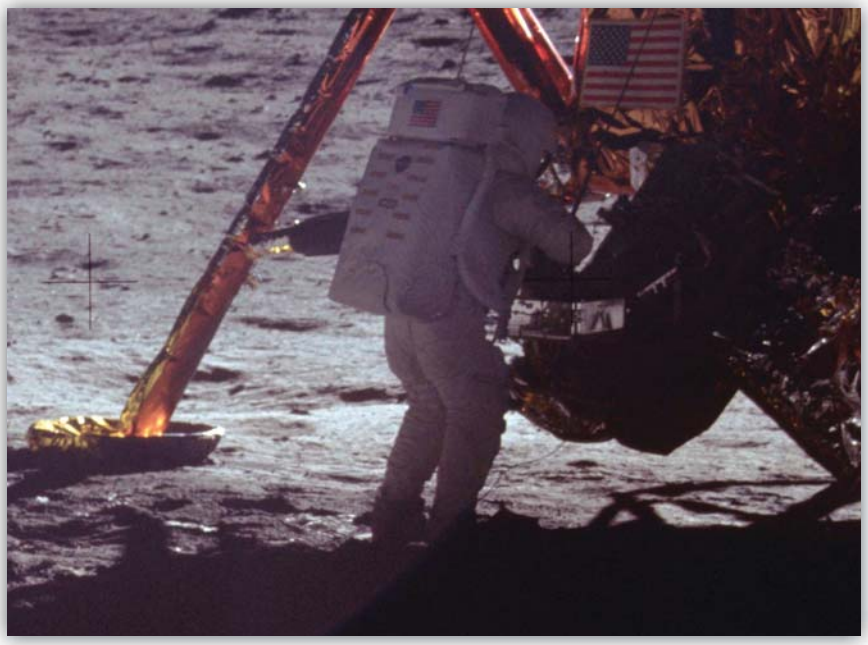
But in 1987 two researchers, H. J. P. Arnold and Keith Wilson, cross-checked the Apollo 11 radio communication transcripts and the astronauts' reports and realized that some of the photographs actually showed Armstrong and not Aldrin as NASA had claimed.[1]

The mistake was partly due to the fact that the moonwalk plan explicitly prescribed that only Armstrong would take photographs of Aldrin, but not vice versa. Moreover, the

1 *Spaceflight*, August and December 1987; *AS11-40-5886*, by Eric M. Jones, Nasa.gov (1995).



Above: Figure 3.1-3. Photo AS11-40-5886 shows Neil Armstrong on the Moon.



On the right: Figure 3.1-4. Neil Armstrong on the Moon. Detail from photo AS11-40-5886.

astronauts' spacesuits had no identifying markings apart from small name tags (starting with Apollo 13, this was fixed by providing the commander's suit with conspicuous red bands).

Thanks to this research, today we know that there are six full-figure or partial photographs of Neil Armstrong on the Moon: the best one is AS11-40-5886 (Figures 3.1-3 and 3.1-4). Not much of a snapshot, but it's better than nothing. Most of all, it shows that independent cross-checks on mission data are feasible and effective and that NASA's word is not accepted unquestioningly.

It's also worth noting that NASA's error was found not by Moon hoax theorists, but by expert researchers, well-versed in spaceflight history, who patiently checked their sources and facts.

Unfortunately, this mislabeling went uncorrected for eighteen years, allowing it to spread and fueling the conjecture that Aldrin refused to take photographs of Armstrong out of spite because he had not been chosen to be the first man to set foot on the Moon.

The other photographs of Neil Armstrong on the lunar surface are:

- AS11-40-5894 (in shadow, underexposed)
- AS11-40-5895 (just his legs)
- AS11-40-5896 (his legs again)
- AS11-40-5903 (his reflection in Aldrin's visor)
- AS11-40-5916 (partial, from the back).

Armstrong is also clearly visible in the Apollo 11 television and film footage.

The tale of this error prompts a question for Moon hoax believers: if the photographs of the first Moon landing were faked for propaganda reasons, then how come NASA didn't fake at least one iconic shot of the first man on the Moon that it could feed to the media?

The photographs

Many people believe that the Moon landings, especially the early ones, took only a handful of grainy, washed-out photographs, because that's what the media usually show, often relying on poor transfers of old copies instead of using pristine digital scans taken directly from the originals.

Actually, the first lunar landing mission, Apollo 11, took 340 high-quality photographs while on the surface of the Moon (217 from inside the LM and 123 during the actual moonwalk).

The other trips took even more pictures on the lunar surface:

- Apollo 12: 583
- Apollo 14: 417
- Apollo 15: 1151
- Apollo 16: 1787
- Apollo 17: 2237

The six Moon landings took a total of 6.515 photographs from the lunar surface. There are also thousands of photographs taken during the flights before and after the actual Moon landings. The grand total is about 19,700.

For many years, books, magazines and newspapers simply used the most dramatic and spectacular photographs of this vast collection and ignored the rest. But today the Internet makes it possible to distribute the entire set of photographs at virtually no cost and reveal the true variety and quality of these historic images.



Figure 3.1-5. Armstrong, Collins and Aldrin inspect 70 mm film rolls.
NASA photograph AP11-69-H-1247.

Their detail is indeed superbly fine. The lunar astronauts used black-and-white and color film in 70 mm format, with three and a half times the area of regular 35 mm film: the same format used by most professional photographers at that time. Their main cameras were custom-built by Hasselblad and mounted Zeiss lenses: the state of the art in mobile photography in the 1960s.



Figure 3.1-6. A Hasselblad 500EL lunar camera.

All these films are still carefully preserved by NASA in a low-temperature vault at the Johnson Space Center in Houston and have been painstakingly digitized. The resulting scans are freely available online with resolutions of up to 4400 x 4600 pixels from websites such as *Apolloarchive.com* and *Eol.jsc.nasa.gov* and in books such as Norman Mailer's *Moonfire*.

These high-quality scans restore the original colors and detail to the Apollo photographs, offering us today a far more complete, fresh and spectacular vision of the lunar excursions of four decades ago than was available to most people at the time of the Moon missions. Moreover, these pictures, besides being a beautiful testimony to the endeavor, allow anyone to cross-check the internal consistency of the documentation of the lunar landings.

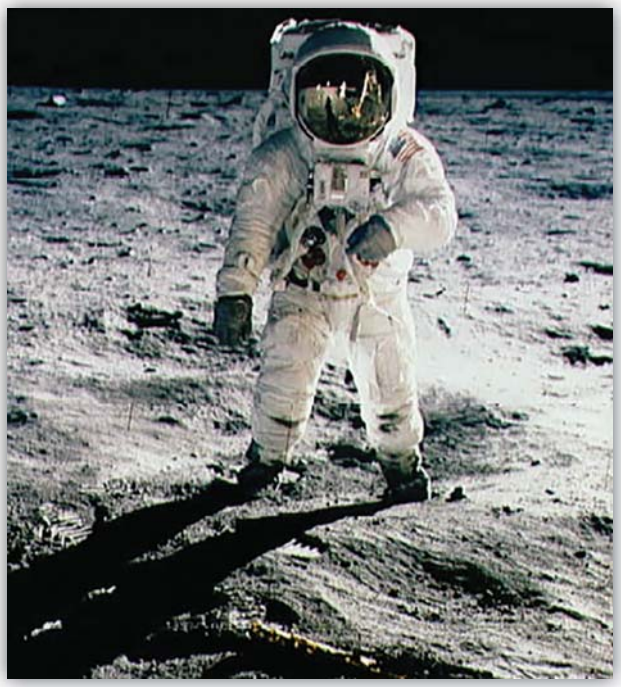


Figure 3.1-7. The classic photograph of Buzz Aldrin on the Moon, AS11-40-5903, as shown online by the JSC Digital Image Collection.

For example, AS11-40-5903 (the famous "tourist photo" of Buzz Aldrin taken by Neil Armstrong during the Apollo 11 mission) is often published in the format and quality shown in Figure 3.1-7.

But if you examine the direct scan of the original film frame (Figure 3.1-8), you find very different, sharper colors and a much wider view, which includes a footpad of the Lunar Module and one of the rod-like probes used by the LM as a ground contact sensor. These probes were located under three of the LM's four circular feet and were bent during landing.

It also turns out that the original shot is quite tilted. Apollo 11's Moon camera didn't have a viewfinder: the astronauts took their pictures by pointing it roughly in the intended direction and relying on the wide viewing angle of the lens. This method usually worked, but in this case Neil Armstrong almost beheaded Aldrin, in the best tradition of tourist snapshots the world over. Indeed, Aldrin's stick-like radio antenna, located on the top of his backpack, is cropped. For all these reasons, this photograph is often printed in the media by straightening it and adding a portion of fake black sky at the top.

The high-quality scan reveals many details of the image that had been wiped out by the excessive contrast introduced by repeated analog duplication processes. It also restores the original clarity of the picture all the way to the horizon, with none of the fading caused by atmospheric haze in pictures taken on Earth, clearly indicating that the photograph was taken in a vacuum.

Also, the direction of the shadows and the inclusion of the footpad and probe of the Lunar Module allow us to locate Aldrin with respect to the vehicle.

Aldrin is standing with the sun behind him and to his left, but the sunlight reflected by the daylit surface all around

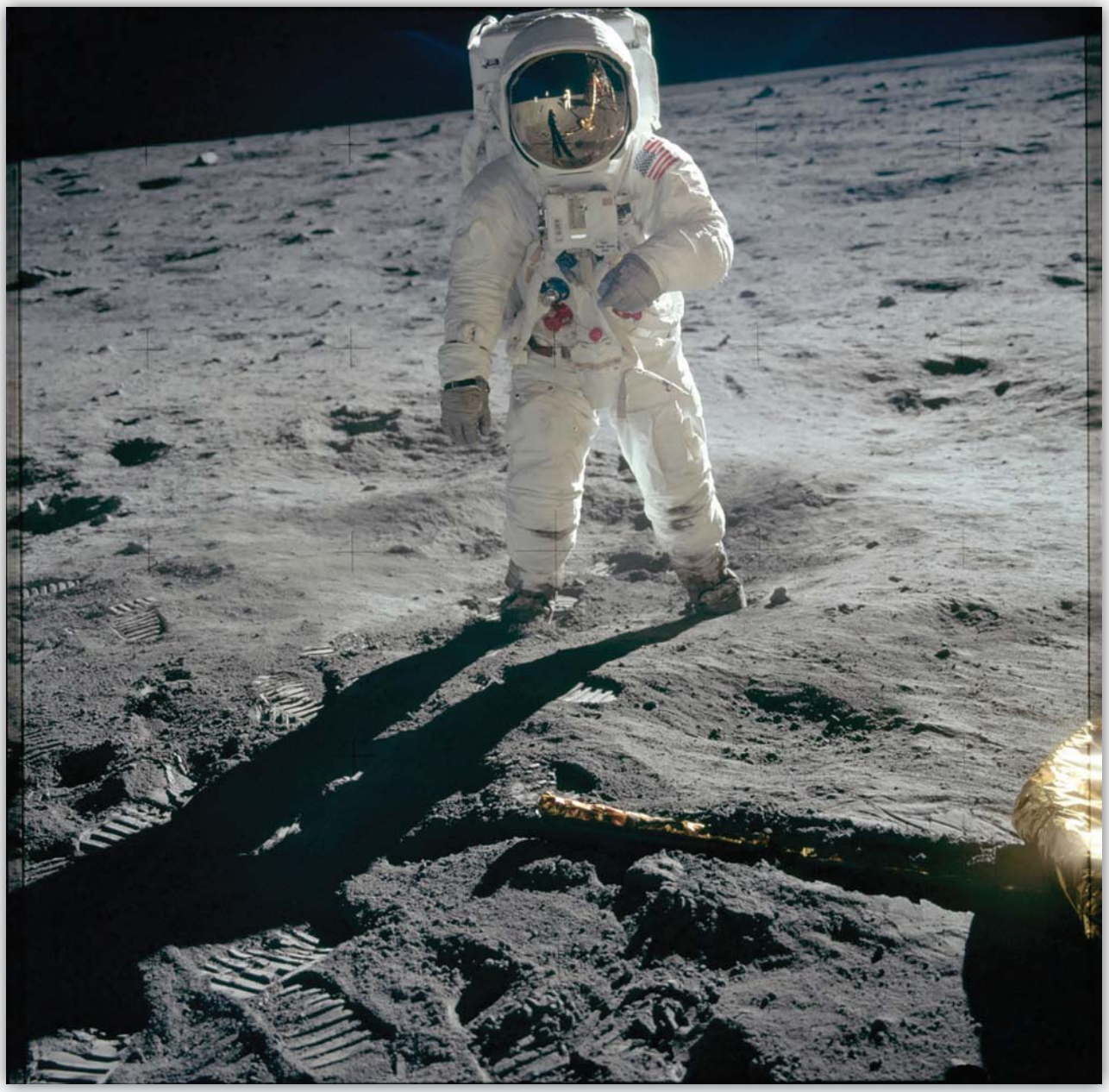


Figure 3.1-8. A higher-quality, full-frame scan of the same photograph, AS11-40-5903. Source: Eol.jsc.nasa.gov.

him and by the metallic film that covers the LM fills in the shadows on his bright white suit.

These higher-resolution scans allow us to explore the Apollo photographs in ways that are entirely impossible with the usual media prints. For example, Aldrin's reflective visor holds the distorted mirror image of his surroundings. With this image quality and with today's digital imaging tools, it becomes possible to analyze the reflection.

The photograph can be flipped to reverse the mirroring effect and then color-corrected to remove the gold hue of the visor, obtaining the detail shown in Figure 3.1-9.

This reveals the scene from Aldrin's viewpoint: the LM to the left, Neil Armstrong (taking the photograph) at the center, with the camera at chest level, the American flag above Aldrin's shadow and the vertical silver strip of the solar wind experiment to the right. Basically, we get to see what was behind the camera, and therefore we can cross-check.



Figure 3.1-9. The reflection in Aldrin's visor in photo AS11-40-5903, reversed and color-corrected, reveals Aldrin's view. Credit: NASA, Kipp Teague, Apollo 11 Image Library.

For example, the portion of the LM footpad visible in the full picture corresponds exactly to the footpad reflected in the visor, and the positions of the flag and solar wind experiment match exactly the other photos and the TV and movie camera footage of the Apollo 11 landing site.

Faking not one, but *three hundred and forty* photographs at this level of resolution and detail and making them perfectly consistent with the live TV broadcast and the 16 mm movie footage would have been astoundingly difficult with the analog photo retouching techniques that were available in the 1960s. An even greater effort would have been necessary for the lunar missions that followed, with their hours of color footage and thousands of photographs.

But there's more. There's a tiny pale blue dot in the black sky reflected in Aldrin's visor, towards the top edge. That dot is right where the Earth would have been in the lunar sky, reflected by an astronaut's visor, if you had placed him where NASA says that Aldrin was standing for this picture: at the Apollo 11 site in the Sea of Tranquility, on the Moon, on July 20-21, 1969.

You can check this with any good astronomy program. From a given point on the Moon, the Earth always has the same position in the sky relative to the lunar horizon (apart from slight changes caused by so-called *libration*), so the exact date isn't too important. Details of the analysis of this blue dot are in the *Apollo 11 Image Library*[2] curated by Eric M. Jones and Ken Glover. Incidentally, the Earth appears tiny in the reflection in the photo because Aldrin's visor is a curved mirror, which reduces the apparent size of objects, especially close to its edge: it's the same effect seen in the passenger-side mirrors of many cars. Seen from the Moon, the Earth actually appears to be about 3.6 times as wide as the Moon is in Earth's sky.

2
[http://tiny.cc/hbdhoz]

This is just one example of the kind of cross-checking that can be done on the freely available data of the Moon

missions. How hard would it have been to fake all this while keeping track of all these minute details?

And if somehow someone pulled off such an amazingly detailed hoax, then how come the same people who bothered to get right even such trivial matters as the reflection of the Earth in an astronaut's visor forgot to put the stars in the photographs or didn't notice a suspiciously flapping Moon flag, as many hoax believers claim?

The live TV broadcast

This cross-checking also applies to the television pictures that were sent live from the Moon. Most moonwalk photographs were taken while the astronauts were in the viewing field of the lunar TV camera and therefore can be compared with the television footage. In all the decades since they were taken, not a single verified mismatch or discrepancy has surfaced.

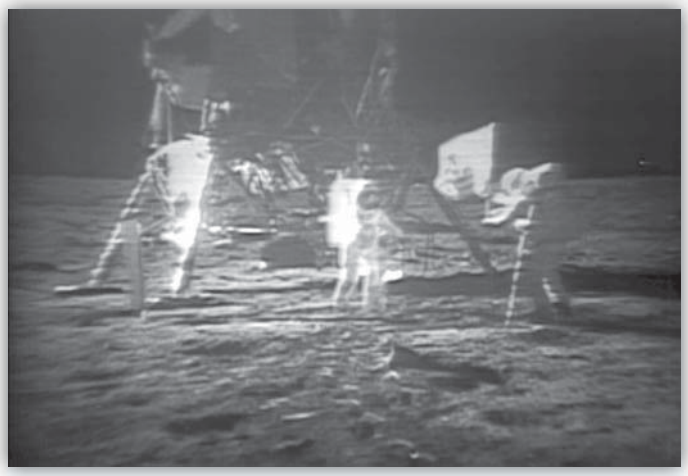


Figure 3.1-10. A frame from the Apollo 11 live television broadcast.

The TV transmissions covered every minute of all the moonwalks (except for Apollo 12's, whose television camera failed a few minutes after the excursion had begun, and Apollo 14's, for which much of the moonwalk was off-camera). This means that for the longer missions there are dozens of hours of recordings, with long uninterrupted sequences, all in color. All this material is available to anyone in unedited form, for example in the excellent DVDs sold by SpacecraftFilms.com.



Figure 3.1-11. The full restored TV broadcast of the Apollo 11 moonwalk. The picture is cropped to adapt it to the 16:9 widescreen format (the original has a 4:3 aspect ratio) [http://tiny.cc/qu3mbz].

The live TV broadcasts also repeatedly show several phenomena that can only occur in an airless, low-gravity environment and could not have been faked with the special effects technology of the 1960s, as we'll see in detail later.

Film footage

The astronauts also used compact movie cameras loaded with 16 mm color film. The image in Figure 3.1-12, for example, shows Neil Armstrong as he climbs down the Lunar Module's ladder to take mankind's first step on the Moon, as shot by Buzz Aldrin with the Maurer movie camera through the right window of the LM.

The first hour and a half of Armstrong and Aldrin's moonwalk is documented in sharp color on movie film as well as by the still photographs and the television broadcast. This footage, too, allows cross-checks.

For example, the Figure 3.1-13 is a detail of a 16 mm film frame showing Aldrin's salute to the flag: this is the same moment captured from a different viewpoint by Armstrong's famous photograph AS11-40-5874 and by the live TV camera (shown in Figure 3.1-15).



Figure 3.1-12. Armstrong climbs down to the lunar surface in a frame from the 16 mm film footage.

Like the television broadcasts, this film footage is fully available and shows phenomena that could only occur in low gravity and in a vacuum, documented with the clarity and vivid color of film.

This is important because it adds further layers of complexity to any alleged fakery. Hiding special effects (for example wires to make the astronauts walk in apparent low gravity) in a hazy TV picture might be conceivable; hiding them from the much sharper eye of a movie camera is an entirely different challenge.

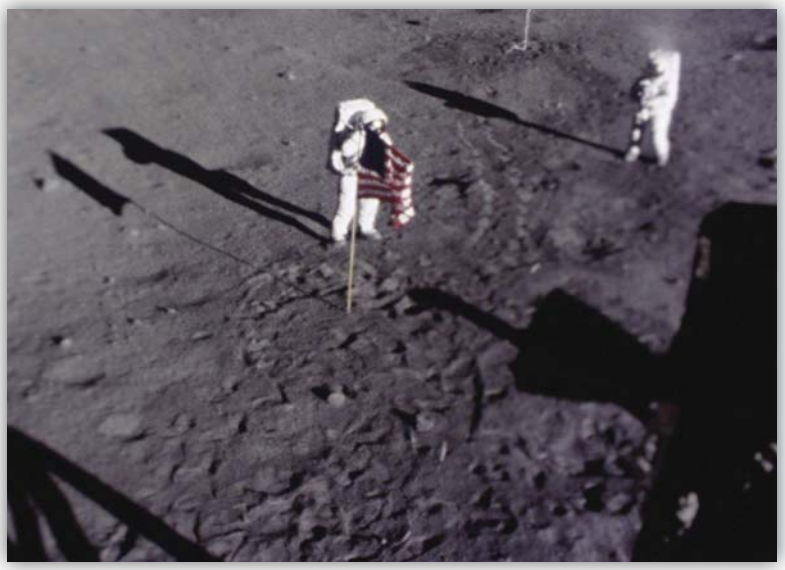


Figure 3.1-13. Apollo 11: Aldrin salutes the flag while Armstrong takes his photograph. Frame from the 16 mm film footage.

Moreover, these hypothetical special effects would have to be accomplished in long, unbroken sequences, without any of the editing and quick scene cuts used by Hollywood to hide the workings of its magic.

Other information sources

The wealth of information on the Moon missions that is publicly available is often greatly underestimated. For example, the complete timeline of all the moonwalks, with the commented transcript of *every single word* uttered on the Moon and every single photograph taken and action performed during the lunar excursions is freely available on the Internet in the *Apollo Lunar Surface Journal*.

Besides countless NASA manuals, handbooks and reports published online, there are many technical books, written by spaceflight experts, that cover the Apollo missions, such as the *Apollo Definitive Sourcebook* by Orloff and Harland, *How*



Figure 3.1-14. Apollo 11: Aldrin salutes the flag. Photo AS11-40-5874.

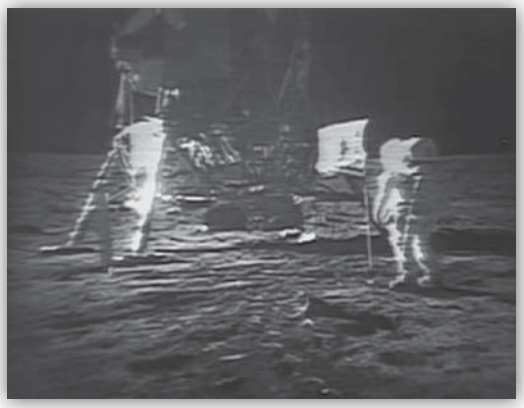


Figure 3.1-15. Aldrin's salute in the live TV footage.

Apollo Flew to the Moon by David Woods, and detailed non-technical accounts such as *Moonfire* by Norman Mailer and *A Man on the Moon* by Andrew Chaikin.

The autobiographies of the lunar astronauts (such as Aldrin's *Return to Earth* and *Magnificent Desolation*, Collins's *Carrying the Fire*, Cernan's *The Last Man on the Moon*) and of the flight directors at Mission Control in Houston (*Failure is not an Option* by Gene Kranz, *Flight* by Christopher Kraft) are also rich in technical details that clarify how we went to the Moon.

Moreover, there is an immense amount of footage covering every aspect of the design, development, evolution, manufacture, testing and launching of the Apollo vehicles. This material is now available both in raw, unedited form from websites such as Archive.org and Footagevault.com and on DVD and as part of many great documentaries, such as *When We Left Earth*, *In the Shadow of the Moon*, *For All Mankind*, *Moonwalk One*[3] and others.

The Internet also provides access to many specialized sites that painstakingly document and catalog the history of spaceflight, such as the vast *Encyclopedia Astronautica*[4], as well as NASA's own websites. The "Moon hoax" claims are also examined and debunked in detail by experts in sites such as AboveTopSecret.com, Clavius.org and many others.

An extensive list of these resources is provided in the *References* chapter.

3
[http://tiny.cc/97dhoz]

4
[http://tiny.cc/lbehoz]

3.2 Cross-checking: the radio delay

A very good example of how all this technical material can be examined, verified and checked for consistency, even in unexpected ways, is the research conducted in 2009 by an Italian physicist, Luca Girlanda, and by the students of two high schools in his country.[5]

5 *Echoes from the Moon,* Luca Girlanda, INFN Sezione di Pisa, in *American Journal of Physics*, September 2009, vol. 77, Issue 9, p. 854-857.

They downloaded from NASA's website the recordings of the radio communications of the Apollo missions from the Moon and noticed that the transmissions included an echo of the voices of Mission Control on Earth. The echo was caused by the fact that the radio signal from Earth reached the astronauts' headsets and was picked up by their microphones, so it was retransmitted back to Earth.



Figure 3.2-1. Neil Armstrong in the LM, tired but clearly pleased after mankind's first moonwalk. Note the twin microphones close to his mouth. Photograph AS11-37-5528.

The students timed this round trip, which occurred at the speed of light: about 2.6 seconds for the Apollo 11 transmissions from the Moon. They also took into account the variations caused by Earth's rotation and by the fact that the transmitter and the receiver were not located in the geometric center of the respective celestial bodies. Then they calculated that this delay implied an Earth-Moon distance of approximately 393,000 kilometers (245,000 miles).

However, the Moon's distance from the Earth changes in the course of its monthly orbit around our planet from 363,100 to 405,700 kilometers (225,600 to 252,100 miles). That's quite a large variation, which causes the round-trip radio delay to also vary between 2.4 and 2.7 seconds. So what was the exact Earth-Moon distance on July 20, 1969? Astronomers can compute the answer: 393,300 kilometers (244,400 miles). In other words, the radio delay that has remained dormant for decades in NASA's recordings is exactly what it should be.

A Moon hoax believer might object that introducing a fixed delay in the radio recordings would have been fairly easy. But there's more. The same high-school students also checked the radio communications of later missions, such as Apollo 17, which remained on the Moon for longer periods, and found that in NASA's original recordings *the delay is variable and matches exactly the variations of the Earth-Moon distance during that period*. That's the kind of minute detail that any hypothetical fakery would have to take into account and get right.

3.3 An impossibly airtight conspiracy

Through the decades that have passed since the Moon landings, not one of the approximately 400,000 civilian technicians and engineers of the many aerospace companies who worked on the Apollo project has ever spilled the beans, not even by mistake or in a moment of alcohol-fueled exuberance.

No deathbed confessions, no leaked dossiers, no compromising photographs revealing the fakery. Even the Mafia can't achieve that level of airtight silence and secrecy. By contrast, the Soviet Union's top-secret Moon landing project and its humiliating failure, described in Chapter 1, became public within twenty years, despite the fact that they occurred in a closed totalitarian regime with sprawling censorship and secrecy systems.



Figure 3.3-1. Some of the engineers who built the Lunar Modules. Credit: Lawrence A. Feliu, Northrop Grumman History Center.

Conspiracy theorists occasionally announce that they have uncovered official documents, photographs or film footage that allegedly have been faked or somehow prove their claims. However, it has always turned out that the fakery was actually on the part of the hoax proponents or that these self-proclaimed detectives had cluelessly misinterpreted their findings, as any spaceflight expert would have told them if they'd bothered to ask.

Moreover, the incredibly tight-lipped engineers of the Apollo project aren't nameless faces: they're real people. Their names are public. They're civilians, not military personnel accustomed to secrecy. Many of them are still alive and quite willing to talk and write about their experience and work on the Moon missions. Yet no conspiracy theorist seems to be willing to accuse them individually, to their face, of faking the Moon landings.



Figure 3.3-2. Left to right: Ted Knotts, Richard Holl and Elmer Fredd celebrate in front of the Scan Converter at Sydney Video. The monitor is showing the Apollo 11 live broadcast. Aldrin and Armstrong are safely back inside the LM. Photo courtesy of Colin Mackellar, Honeysucklecreek.net.

Also, the Apollo project didn't just involve Americans. Scientists and engineers from all over the world took part in the science experiments and communications. The solar wind experiment was managed by Swiss researchers. The telemetry, television and radio links with the spacecraft were relayed by Australian and Spanish tracking stations. The knowledge gained from the Moon landings has been shared for decades with scientists of all countries. Subsequent uncrewed Moon missions of many countries relied on Apollo

data. European astronauts have been trained by Neil Armstrong and other moonwalkers. Are all these skilled professionals too dumb to realize they’ve been hoodwinked all this time?

3.4 The silence of the Soviets

As detailed in Chapter 1, the Soviets attempted to land a cosmonaut on the Moon ahead of the Americans. The two superpowers' standing in the world was at stake and a show of technological prowess would send a clear message to non-aligned countries that the Soviet Union was a powerful, modern and determined state that it would be wise to have as an ally. But the costly Russian attempt failed catastrophically and was kept secret. The Soviet government pretended that it had never tried to set foot on the Moon.

Therefore, if the Soviet Union had discovered that the American Moon landings had been faked – something which it was well equipped to do, through both radio eavesdropping and espionage – it would have had excellent reasons to reveal any American trickery and thus publicly humiliate its rival and enemy, providing irrefutable evidence, as it had during the U-2 incident in 1960.[6]

6 As mentioned in Chapter 1.3, when the CIA realized that it had lost one of its secret U-2 spy planes over the Soviet Union, NASA released a cover story claiming that it was one of its weather research aircraft that had gone off course due to a malfunction, but the Soviets (who had shot the plane down) later presented the unmistakable military reconnaissance equipment found among the wreckage and revealed that they had captured the pilot, Francis Gary Powers. This led to a devastating political and diplomatic humiliation for US president Eisenhower, and nobody questioned the Soviet revelations.

But the Soviet government didn't dispute the landings. On the contrary, in an unprecedented gesture, Soviet state television announced Apollo 11's Moon landing and even broadcast excerpts from the mission's moonwalk. The Soviet state newspaper, *Pravda*, mentioned the moon landing on its front page on July 21, 1979. Soviet state-controlled media covered the mission extensively.

When the crew returned to Earth, Moscow Radio began its evening newscast by reporting that *"the courageous astronauts, Armstrong, Aldrin and Collins are again on our planet"*.

Soviet head of state Nikolai Podgorny wired US president Nixon after the Apollo 11 splashdown:

"Please convey our congratulations and best wishes to the courageous space pilots."



Figure 3.4-1. A Romanian stamp series describes Apollo 11 as the "first Moon landing of a human crew".



Figure 3.4-2. A 1977 stamp from Czechoslovakia. Credit: 123rf.com.

Many countries of the Soviet bloc issued stamps celebrating the Apollo 11 mission.

The *Great Soviet Encyclopedia*, published in 1970, dedicated two pages to

the Apollo flights and half a column to Neil Armstrong's biography.

After the collapse of the Soviet Union, several key figures of the country's space program, such as designers Vasily Mishin and Boris Chertok, wrote books explaining the reasons for the failure of Soviet crewed lunar efforts and commended the success of the American missions that put astronauts on the Moon.

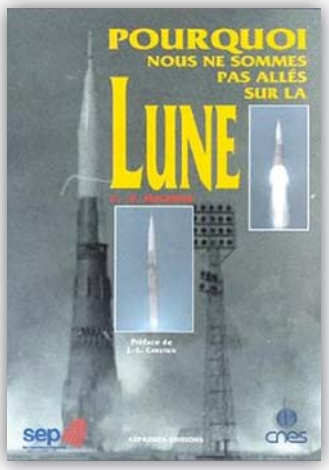


Figure 3.4-3. The front cover of the French edition of Vasily Mishin's book on the failure of the Soviet lunar program, entitled Why we didn't go to the Moon *(1993).*

3.5 Voices from the Moon



Figure 3.5-1. Assembly of a 9-meter dish near Gainesville, Florida, to pick up Apollo 17 radio communications, November 1972. Credit: Sven Grahn.

Further evidence that astronauts actually went to the Moon is the fact that their radio communications could be received by anyone on Earth with suitable equipment. Sven Grahn, scientist and researcher for the Swedish space program and expert radio tracker of spacecraft, followed Apollo 17's flight to the Moon with a 9-meter parabolic dish antenna in 1972. His team was able to pick up astronaut Ron Evans' voice communications from the Command Module as it orbited around the Moon. The technical details of this achievement and of the radio signals sent by the Apollo spacecraft are published in his article *Tracking Apollo-17 from Florida* at *www.svengrahn.pp.se*.

The Italian radio telescope at Arcetri, near Florence, picked up the voice communications of the Apollo 11 astronauts as they descended to the Moon. Professor Guglielmo Righini, director of the observatory, and chemistry-physics professor Salvatore Califano of the University of Florence, vividly describe their scientific eavesdropping on the conversations of the Apollo astronauts:



Figure 3.5-2. Professor Guglielmo Righini (1908-1978).

> *Professor Righini explained that at Arcetri, the physicists from Florence followed the American space endeavor from its beginning, staying permanently in indirect contact with the spacecraft and listening to the conversations of the astronauts when they occurred on a particular wavelength to which the Arcetri instrument was tuned and when, before the Moon landing, the American spacecraft orbited around the near side of the Moon.*
> -- Attraverso i sassi lunari studieremo il sistema solare*, by Carlo Degl'Innocenti, in* L'Unità*, 22 July 1969, page 5.*

These signals are very strong evidence that the Apollo spacecraft actually did go all the way to the Moon for several reasons. First of all, the very large antennas used by these non-NASA receivers are highly *directional*: in other words, they only hear signals that come from the very small spot in the sky towards which they are pointed. If the Apollo signals were picked up by the antennas while they were pointed at the Moon, the signals had to come from the Moon. These signals could not arrive from, say, an Earth-orbiting artificial satellite, because such a satellite would have move in the sky much faster than the Moon in order to stay in orbit.

Secondly, the Apollo signals exhibited *Doppler shift*: their frequency shifted when they moved periodically towards and

away from the receivers as the spacecraft orbited around the Moon. The values of this shift allowed to determine the speed of the vehicles and confirm that they were orbiting around the Moon at the speed and distance stated by NASA or had landed on the Moon.

In other words, voices from the Moon were received independently on Earth by researchers. Anyone claiming a conspiracy would therefore have to explain, in technical detail, how these signals could be faked so well as to fool scientists or would have to accuse Sven Grahn and professors Righini and Califano of being liars.

3.6 Moon rocks

The 382 kilograms (842 pounds) of handpicked samples of Moon rock brought back by the six crewed landings are often mentioned as evidence that astronauts walked on the Moon. The nonterrestrial nature of these over 2,000 samples has been confirmed by the studies conducted by geologists from all over the world during the last forty years.

The photograph in Figure 3.6-1 shows one of these alien samples, known as the *Genesis Rock* because it is approximately four thousand million years old and is one of the most ancient rocks ever found. Dave Scott and James Irwin collected this 269-gram (9.5-ounce), 9-centimeter (3.5-inch) sample during Apollo 15.

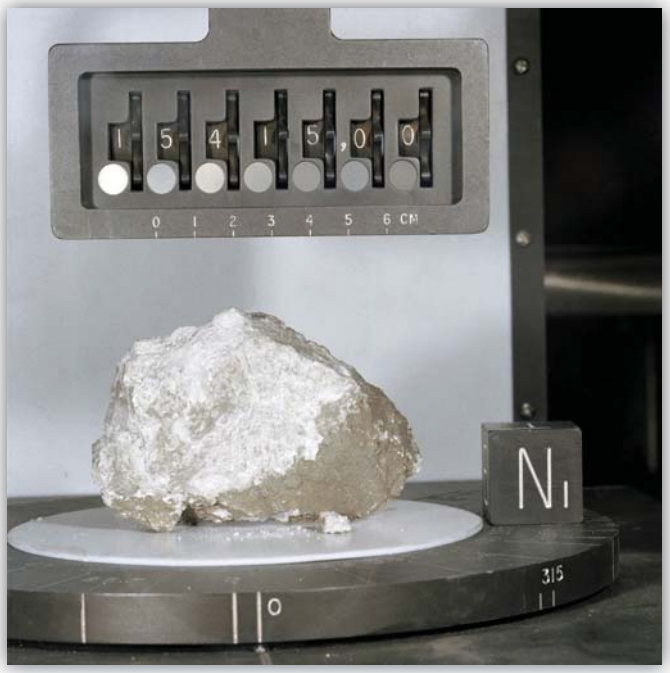


Figure 3.6-1. The Genesis Rock returned from the Moon by Apollo 15.

A hardcore Moon hoax believer might object, however, that the Soviets, too, brought back rock samples from the Moon by using the Luna 16, 20 and 24 automatic probes, launched between 1970 and 1976. Therefore it would be fair to argue that maybe the US did the same. Indeed, strictly speaking, the lunar rocks prove that the United States sent *vehicles* to the Moon but don't necessarily prove that *astronauts* went to the Moon.

However, there are substantial differences between the Soviet and American sample returns that allow us to include the Moon rocks among the evidence of human lunar landings.

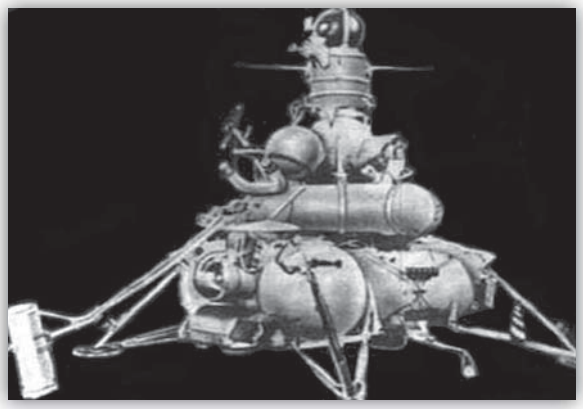


Figure 3.6-2. A Soviet Luna probe equipped for Moon soil sample return.

First of all there's quantity. The total weight of all the Moon rock samples collected by the Russian robotic probes is 326 grams (11.5 ounces); the American samples weigh over a thousand times more. This difference highlights the huge gap in performance between US and Soviet spacecraft. It shows that NASA was capable of sending to the Moon and returning home a far larger payload per mission than its Russian counterpart. Apollo 17 alone brought back 110 kilograms (242 pounds) of samples.

At the very least, this undermines the conspiracists' claims that the Saturn V booster was an inadequate Moon vehicle. If a single Saturn V rocket and the Apollo spacecraft were capable of returning 110 kilograms (242 pounds) of lunar

rocks, it stands to reason that they were capable of carrying at least one astronaut to the Moon and back.

Then there's quality. The Soviet "rocks" are actually little more than coarse grains like the one shown in Figure 3.6-3, which is 2.5 millimeters (one tenth of an inch) long. It's smaller than a grain of rice. Moreover, the Soviet samples were not selected in any way.

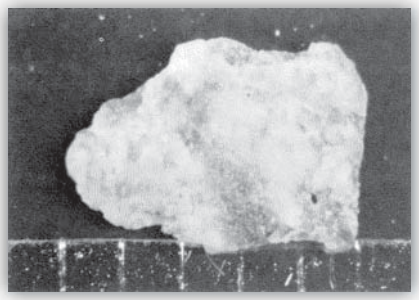


Figure 3.6-3. A sample of the lunar surface returned to Earth by the Soviet Luna 20 uncrewed mission in February 1972 and loaned for examination to geologists from Caltech, Oregon State University and University of Chicago. Credit: Engineering and Science*, May-June 1976, page 19.*

By contrast, the highly diverse Moon rocks returned by the United States weigh up to *11 kilograms (24 pounds)* each. Some are core samples taken by drilling up to 3 meters (9 feet) into the ground. The best the Soviets managed was a core sample weighing all of 170 grams (six ounces). It was the only sample returned by the Luna 24 mission, and this was achieved in 1976, seven years after Apollo 11.

How could all this have been achieved? Is it more likely that the US somehow, in the 1960s, had incredibly advanced secret robotic technology, or that it sent astronauts to the Moon with the geological knowledge and the right tools to choose the rocks and drill the core samples manually?

One more thing. Moon hoax believers who raise the issue of the Soviet lunar samples paint themselves into a corner, because Soviet samples are geologically identical to the ones returned by the Apollo missions and are different from Earth rocks. In other words, the Soviet rocks authenticate the American ones. Which means that any hoax believer who mentions the Russian Moon samples can't claim that the Apollo rocks are fakes.

3.7 Mirrors on the Moon

The "mirrors" placed on the lunar surface by the astronauts are another frequently cited example of evidence of the crewed Moon landings. Actually, they're not mirrors, but arrays of high-precision prisms, known as *retroreflectors*, that reflect light exactly in the direction from which it came, like a bicycle reflector.

These passive devices, requiring no onboard power for their operation, were placed on the lunar surface by the crews of Apollo 11, 14 and 15. Even today, scientists can fire a high-power laser beam from Earth to the locations of these retroreflectors on the Moon and detect the light that they reflect back. The time it takes for the light to complete the round trip allows researchers to measure the

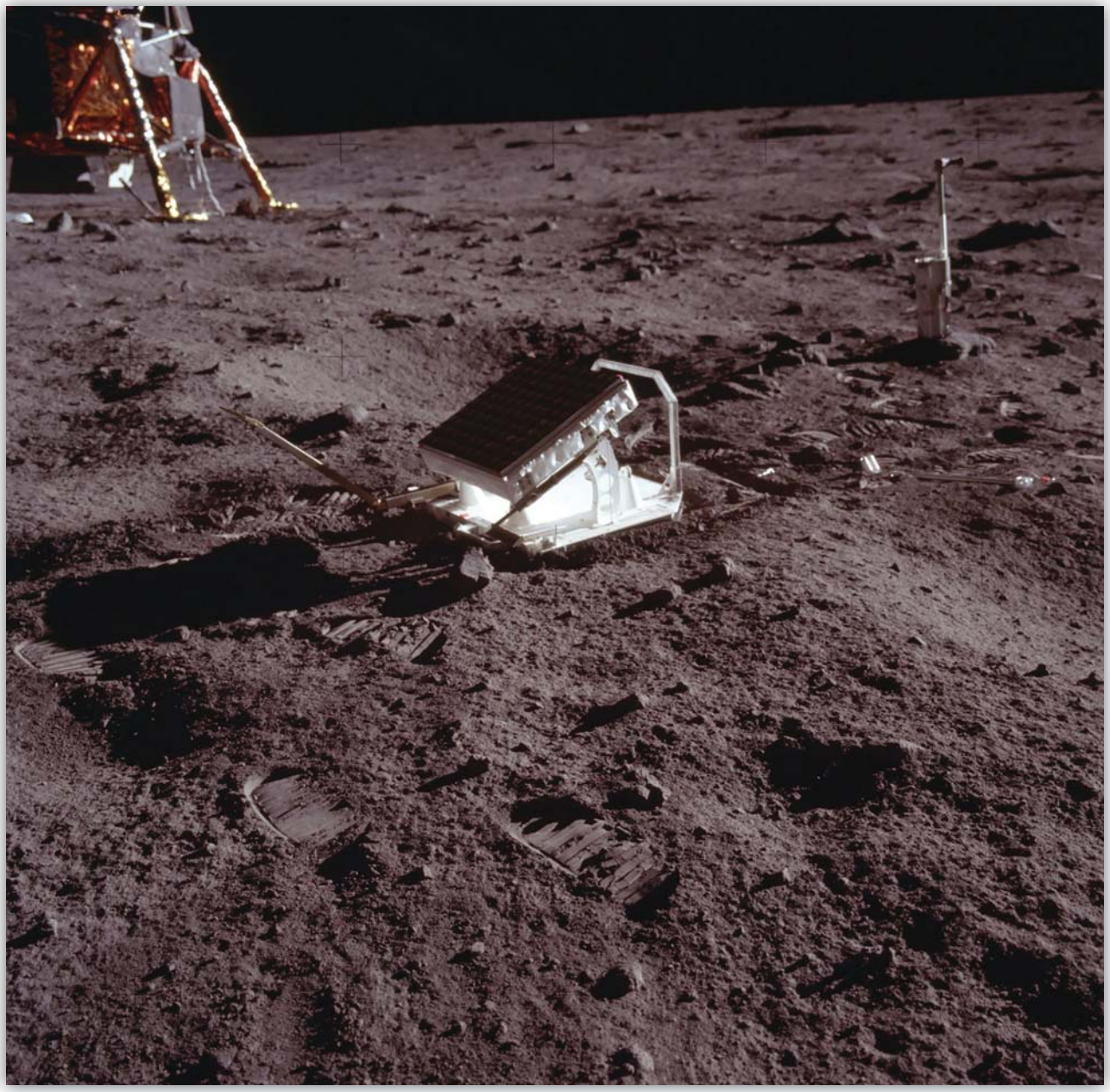


Figure 3.7-1. The Apollo 11 retroreflector. Detail from photo AS11-40-5952.

Earth-Moon distance to within a few centimeters (inches) and to conduct many astronomy- and gravity-related studies.

One of the retroreflectors built for the Apollo program is on display at the National Air and Space Museum in Washington, DC.

Strictly speaking, however, these devices cannot be used as indisputable evidence of *crewed* Moon landings, because the Russians managed to place their own retroreflectors on the Moon by using uncrewed probes (Luna 17 and Luna 21, in 1970 and in 1973). But they do prove that the United States, in 1969 and in 1971, were actually able to somehow place these instruments exactly where they claim to have landed astronauts on the Moon.



Figure 3.7-2. High-power laser beams fired at precise locations on the Moon from the Goddard Geophysical and Astronomical Observatory strike the Apollo retroreflectors. Credit: NASA, 2007.

3.8 Photographs of the vehicles left on the Moon

Can't we simply point a telescope at the Moon and see if the Apollo vehicles are there? It's one of the most frequent and common-sense questions regarding Moon hoax theories.

The answer, unfortunately, is no: even the world's most powerful telescopes are currently unable to resolve such tiny objects at the distance of the Moon, for reasons detailed in Chapter 7. However, if a telescope were placed closer to the Moon, for example on an uncrewed space probe, it could take pictures of the sites where NASA claims to have landed.



Figure 3.8-1. Artist's rendering of the Lunar Reconnaissance Orbiter.

Actually, this has already been done. In 2009, NASA's Lunar Reconnaissance Orbiter probe began a high-resolution survey of the entire Moon which is still in progress today. The probe's state-of-the-art mapping camera has taken many photographs of the landing or crash sites of many US and Soviet space probes, including the Apollo spacecraft. In 2011 it flew as low as 22 kilometers (13.6 miles, 72,000 feet) in the vicinity of some of the Apollo sites and imaged details as small as 0.25 meters (about 10 inches).

The LRO images of the Apollo landing sites show that the descent stages of the Lunar Modules and the equipment left on the Moon by the astronauts are still there today, exactly where NASA described and documented them with on-site photographs, TV and movie footage so many decades ago.



Figure 3.8-2. The descent stage of Apollo 17's Lunar Module, photographed on the Moon by the LRO probe in 2011. Credit: NASA/GSFC/Arizona State University.

These images even show the parallel tread marks left by the wheels of the Rover and the lines of footprints produced by the astronauts. On the Moon there's no wind or rain to make them fade, so they're still there right now.

Figures 3.8-2 and 3.8-3, for example, are photographs of the Apollo 17 landing site taken by the LRO in 2011. They show the descent stage of the Lunar Module *Challenger*. Its sharp shadow reveals how high it protrudes above the surrounding surface. The ground around the LM is darker because it was disturbed by Gene Cernan and Harrison Schmitt's boots.

The Lunar Reconnaissance Orbiter has imaged the Apollo landing sites repeatedly and is still doing so periodically. For example, the larger white spot in Figure 3.8-4 is the descent stage of the Apollo 11 Lunar Module and the four

dots around it are the LM's footpads, in different lighting conditions: respectively, with the sun at a low angle and at a high angle to the local horizon, thus casting long and short shadows.

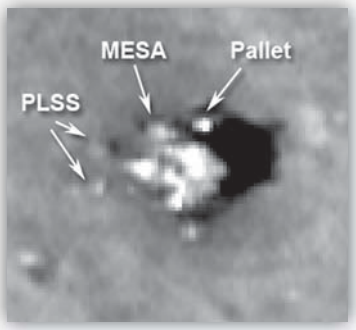


Figure 3.8-3. Detail of the Apollo 17 LM descent stage imaged by the LRO probe in 2011. PLSS *indicates the astronauts' backpacks;* MESA *is the tilt-down equipment stowage compartment on the descent stage;* Pallet *is the payload transport pallet. Credit: NASA/GSFC/Arizona State University.*

The arrows indicate the television camera (*TV*), the retroreflector (*LRRR*), the seismograph (*PSE*) and the line of footprints left by Neil Armstrong when he dashed to Little West crater, about 60 meters (200 feet) from the LM, and took a series of photographs, such as AS11-40-5961, as attested by the radio communications recordings and by the mission reports. The TV recordings show the initial part of Neil's dash.

That's the level of cross-checking allowed by the Moon landing data. And there's more.

The LRO photographs of the Apollo 11 site can be compared with the lunar excursion map published in 1969 by NASA (Figure 3.8-6), which details the locations of the items left on the Moon and traces the astronauts' movements. It turns out that all the objects, the bootprints and the terrain details we find on the Moon today are almost exactly where NASA said they were over four decades ago.

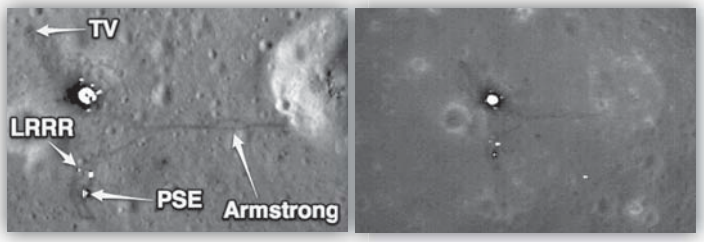


Figure 3.8-4. Left: the descent stage of Apollo 11, photographed by the LRO with the sun at a low angle to the horizon in 2011. Right: the same site imaged with the sun almost overhead in 2009. Credit: NASA/GSFC/ Arizona State University.

The Apollo 11 landing site has been photographed by the LRO so many times through the years that it is possible to combine the photographs into a sequence (Figures 3.8-7 and 3.8-8) which shows the Lunar Module descent stage in various lighting conditions, clearly bringing out its three-dimensional shape and its details.

The Figures from 3.8-9 to 3.8-12 are images of other Apollo landing sites taken by the LRO.

To better understand the details of these images of the Apollo landings site it can be useful to refer to Figure 3.8.13, which is a **digitally edited** photograph from the Apollo 16 mission. It shows how the LM descent stage would appear after the crew lifted off in the ascent stage.

This digital artist's impression highlights the little-known fact that the four exhaust plume deflectors, used to prevent the exhaust of the maneuvering motors from striking the spacecraft and damaging it, were part of the descent stage and therefore were left on the Moon. Today they rise above the descent stage and form shadows on its top.

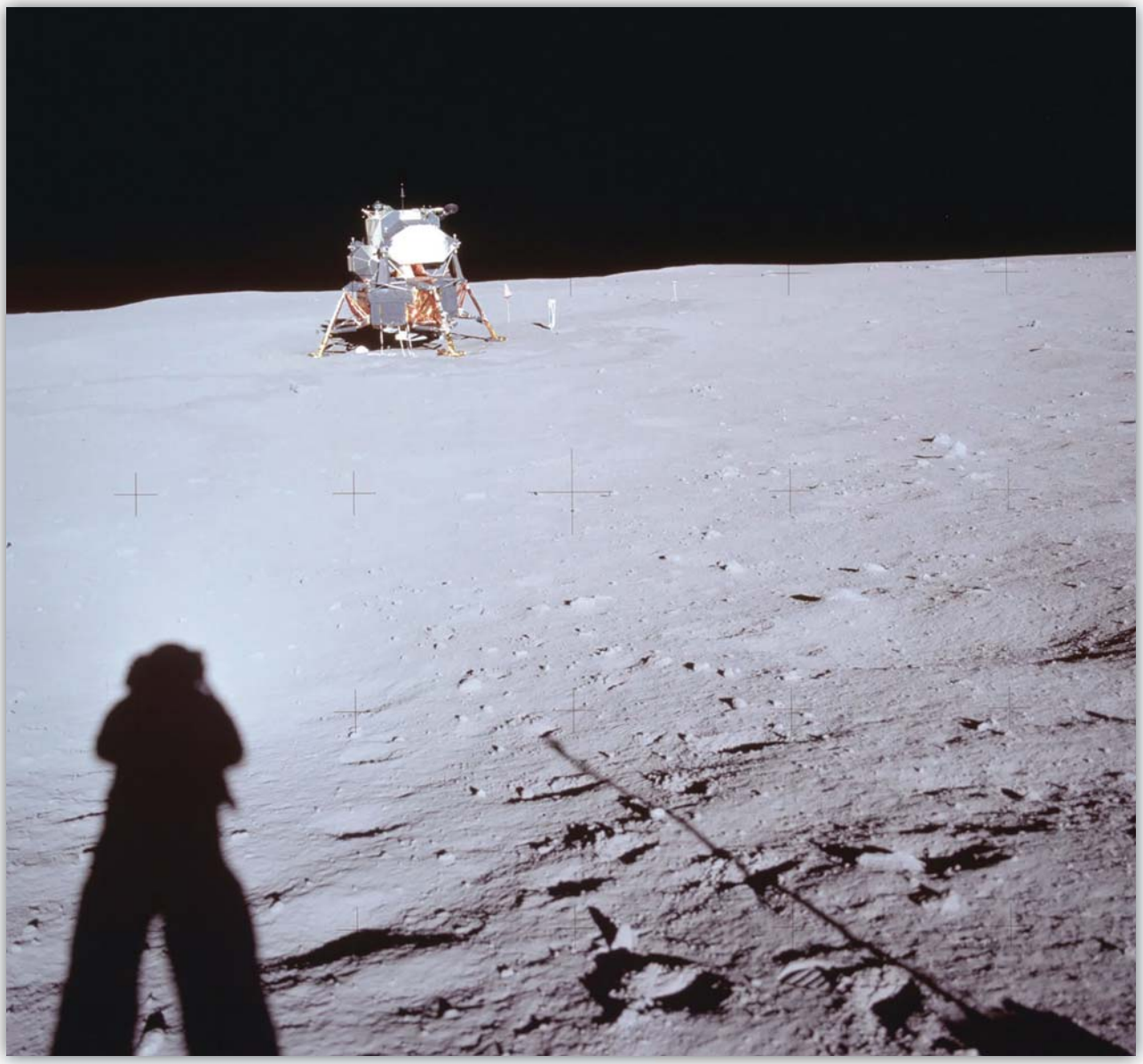


Figure 3.8-5. Neil Armstrong on the rim of Little West crater. The thin shadow on the right is cast by the ALSCC instrument (stereo macro camera for geology imaging). NASA photograph AS11-40-5961.

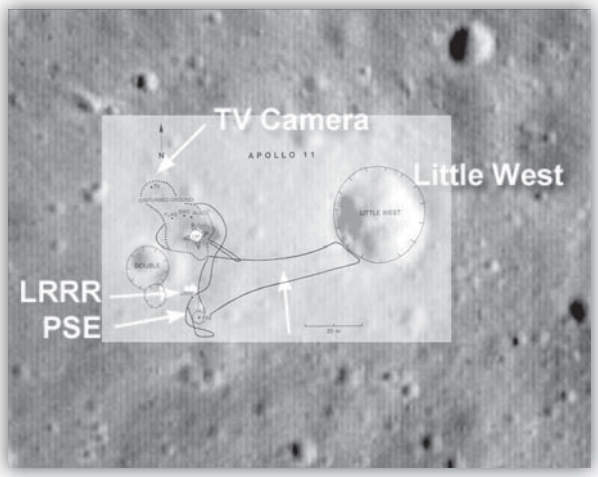
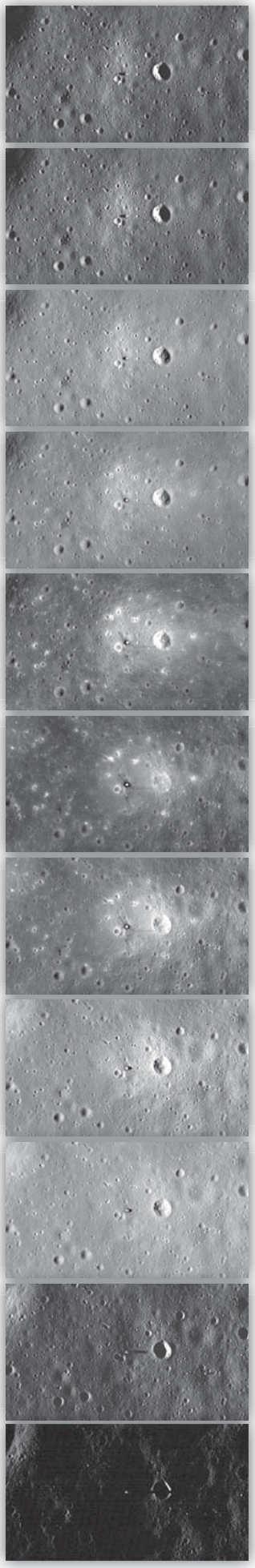


Figure 3.8-6. Comparison between the Apollo 11 Traverse Map *(1969) and a site photograph taken by the LRO probe (2009). Credit: NASA/ GSFC/Arizona State University.*



On the left: Figure 3.8-7. Animation of LRO images of the Apollo 11 landing site. Changes in lighting clearly show the LM casting a shadow and catching sunlight. Credit: NASA/GSFC/Arizona State University, 2018.

On the right: Figure 3.8-8. Another animation of LRO images of the Apollo 11 landing site. This image sequence is rotated 90° counterclockwise with respect to Figure 3.7-7. Credit: NASA/GSFC/Arizona State University.



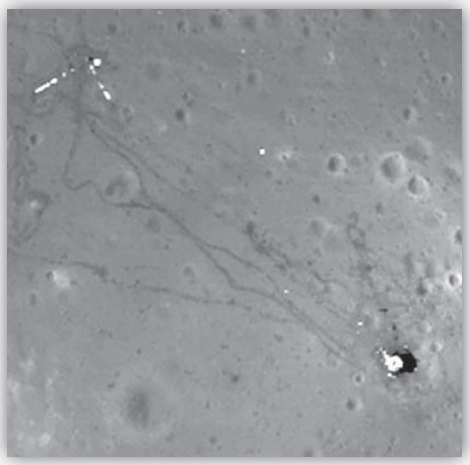


Figure 3.8-9. The Apollo 12 landing site, imaged by the LRO probe in 2011. Credit: NASA/GSFC/Arizona State University.

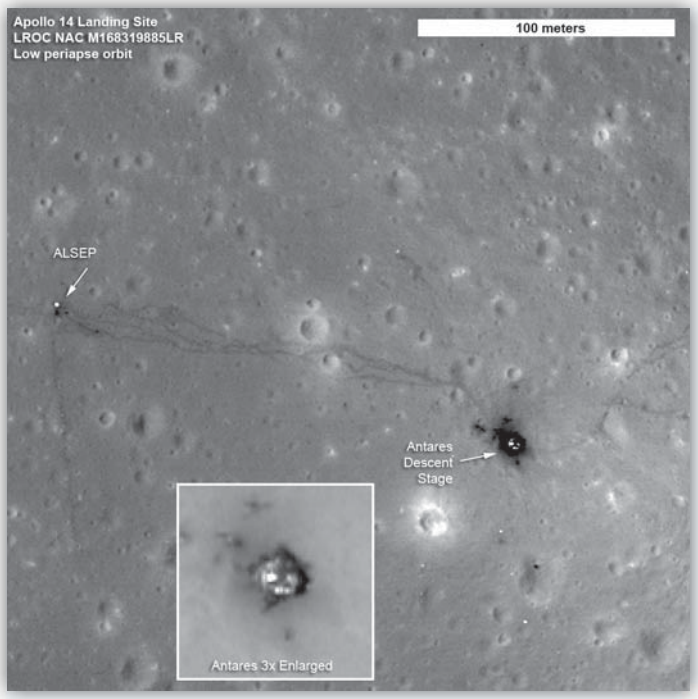


Figure 3.8-10. Detail of the Apollo 14 landing site, taken by the LRO in 2011. Credit: NASA/GSFC/Arizona State University.

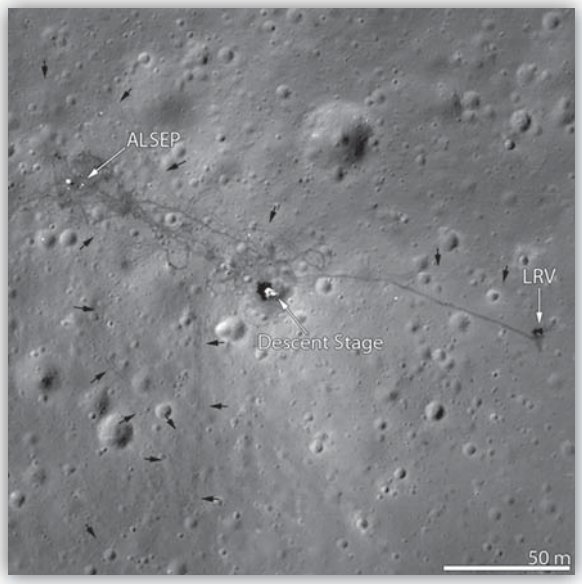


Figure 3.8-11. Detail of the Apollo 15 landing site, imaged by the LRO in 2012. Credit: NASA/GSFC/Arizona State University.

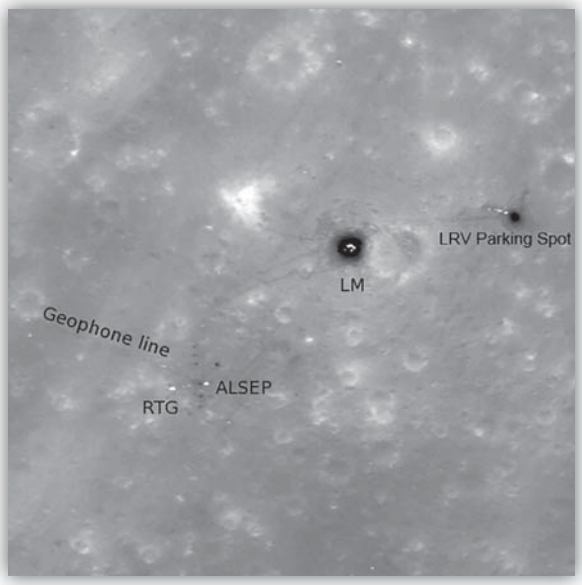


Figure 3.8-12. The Apollo 16 landing site, photographed by the LRO in 2010. Credit: NASA/GSFC/Arizona State University.

Someone might object that the LRO is a NASA probe and therefore cannot be trusted. Actually, NASA only *launched* the probe: the LRO's camera and the analysis of its images are managed by a separate academic group, the LROC Science Operations Center at the Arizona State University, together with other scientific organizations. The LROC website provides the full list of participants.

All these people, too, would have to be part of the massive cover-up, or someone would have to fake all the pictures that keep coming from the Moon. The fakery would have to be so perfect that the researchers at the Arizona State University and elsewhere wouldn't realize they were being duped. Considering that they're digital imaging analysis experts and that fake images would have to be generated whenever the LRO flies over the six Apollo landing sites and would have to take into account the ever-changing sun angle, that's quite a substantial challenge.

A single slip in any point of this process would reveal the entire decades-old conspiracy to the world, because the Lunar Reconnaissance Orbiter pictures are regularly posted on the probe's website at *www.lroc.asu.edu*.

It strains credulity to claim that any government agency could attain and maintain this level of absolute secrecy and perfection for so many decades.

Another, perhaps more sensible objection might be that the LRO photographs only show the *vehicles*, but obviously not the astronauts. But if so, how were the bootprints made? Did NASA secretly send a robot with boots to the Moon, to trace the exact patterns faked on the movie set? *Six times?*



*On the left: Figure 3.8-13. **Digitally edited** version of NASA photo AS16-107-17435 (Apollo 16) showing the likely appearance of a lunar module after crew liftoff. Credit: Joel Raupe (@LunarPioneer).*

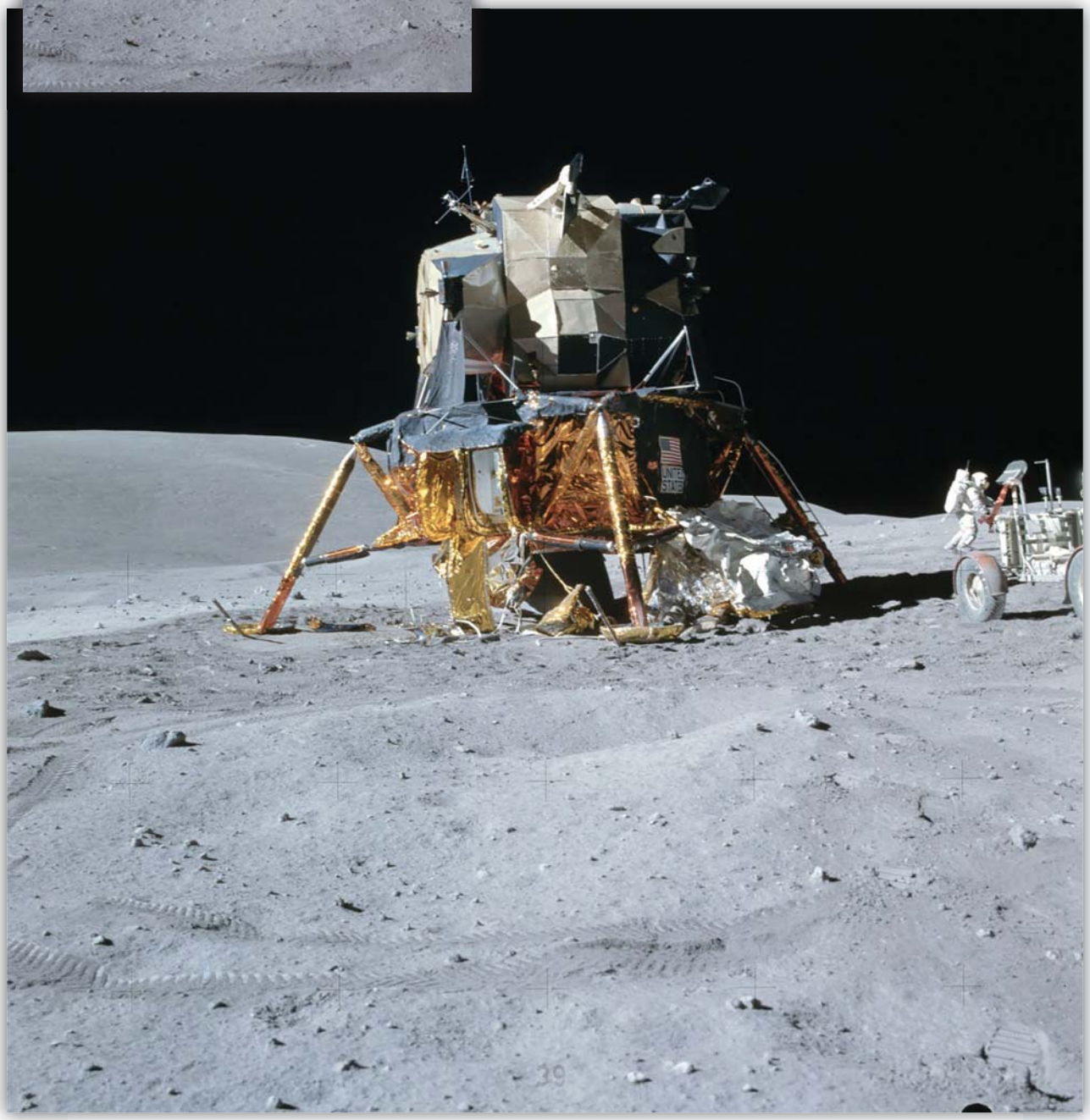


Figure 3.8-14. The full, unretouched source of Figure 3.7-12: NASA photo AS16-107-17435.

3.9 Evidence, but not proof

So far we've seen strong indications of the authenticity of the crewed Moon landings, which are quite convincing for anyone who considers the balance of evidence. They show that any attempt at fakery would have been absurdly complicated, but they aren't *proof*, strictly speaking. Certainly they're not definitive proof for a hardcore Moon hoax believer.

If we're looking for proof, what we need is something that demonstrates beyond doubt that in 1969 there were no bizarre robots in boots hopping around on the Moon, but that *human beings* were actually there. Something that documents an event that could have occurred only on the Moon half a century ago and in the presence of astronauts. Something preferably provided by an independent source, not by NASA.

Surprisingly enough, such proof exists.

3.10 Japan's 3D Moon maps

The Kaguya/Selene automatic Moon probe, launched by the Japanese space agency JAXA, spent 20 months orbiting the Moon, ending its mission in 2009. Its laser altimeter had a vertical precision of 5 meters (about 16 feet), which allowed JAXA's scientists to generate highly accurate digital 3D maps of the Moon's surface. The map data are available at Kaguya's website.



Figure 3.10-1. Artist's rendering of the Japanese Kaguya probe and of its two subsatellites, Okina and Ouna. Credit: JAXA.

The highly detailed pictures from Kaguya's camera can be combined with the altimeter's 3D terrain measurements to generate virtual views of the moonscape as seen from any point on or above the lunar surface.

The Japanese space agency's engineers tested Kaguya's systems by comparing their results with NASA's, using only their own data to generate a digitally rendered view of the lunar surface as it would appear if the observer stood at the site where the Apollo 15 astronauts took a series of photographs in July 1971 and looked in the same direction as they did. The comparison is shown in Figure 3.10-2 and speaks for itself.

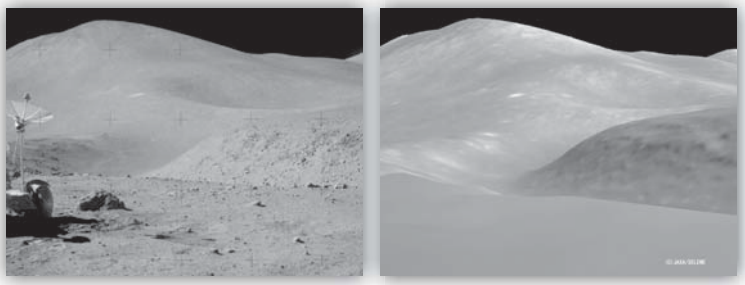


Figure 3.10-2. Left: a detail of NASA photo AS15-82-11122, taken in 1971 by the crew of Apollo 15. Right: the digitally rendered view from the same spot on the Moon, based on the 3D maps and photographs generated from the data of Japan's Kaguya probe in 2009.

The object on the far left in the NASA photograph is a portion of the Lunar Rover, the electric car used by the astronauts. Indeed, the other photographs of the NASA sequence include astronaut David Scott, who is working on the Rover, as can be seen in the composite picture shown in Figure 3.10-3.

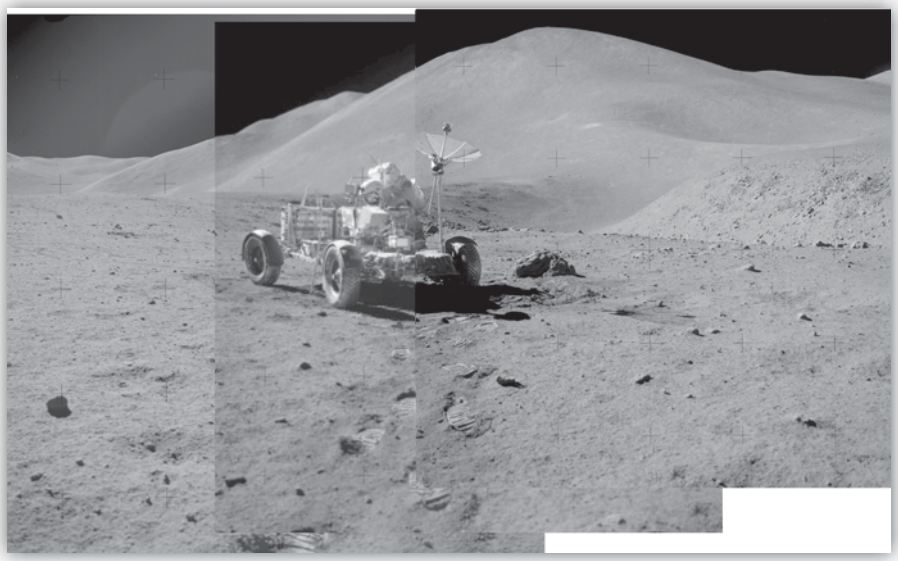


Figure 3.10-3. Composite image of NASA photos AS15-82-11120, AS15-82-11121, AS15-82-11122 from the Apollo 15 mission (1971). The astronaut leaning over the Rover is David R. Scott.

In other words, in 1971 NASA published photographs that showed a lunar mountain range seen from a specific point on the surface of the Moon and included an astronaut and his vehicle. Thirty-eight years later, a Japanese

probe went to the Moon, scanned that same mountain range and found that the view from that specific location matches exactly what NASA had shown nearly four decades earlier in the Moon landing pictures. How did NASA know in 1971 what that ground view looked like? How did it get a Rover and an astronaut in the picture?

Perhaps NASA secretly carried to the Moon a Rover, a dummy dressed in a spacesuit, and a robot that set them in position, took their photograph and returned the high-resolution film to Earth. But that would imply that in 1971 the US space agency was already capable of performing extremely complex Moon missions with substantial payloads. But if it had such an advanced capability, then it would have been able to put *real* astronauts on the Moon.

Or maybe the US sent an automatic probe to the Moon in 1971 or earlier and gathered high-precision altimetric data of the contour of the lunar surface, or took photographs from ground level, and then built movie sets that replicated exactly the actual appearance of each Moon landing site.

But it would be ludicrous to think that a government organization could carry out successfully such a complex operation in absolute secrecy, and do so six times, involving inevitably a very large amount of people to create the fakery, without anyone ever making mistakes or revealing too much, without ever losing any of the paperwork involved, and with the risk of catastrophic humiliation in case of a slip-up.

It would have been far easier to actually go to the Moon, and it would have been politically safer: even in case of failure, at least there would have been no danger of being caught faking it.

3.11 Telltale moondust

There's another apparently trivial aspect of the visual record of the Moon missions that hoax proponents have great trouble explaining: the dust.

On Earth, the dust kicked up by the wheels of a car, for example, stays in the air for a long time, producing a long billowing cloud that dissipates slowly, such as the one shown in Figure 3.11-1.



Figure 3.11-1. Dust cloud on a dirt road. Credit: PA.

However, in the color film footage of the astronauts' electric car ride on the Moon the fine dust that it kicks up falls immediately to the ground in a parabolic arc. That's because on the Moon there's no air to brake its fall and keep it floating. This footage, therefore, must have been shot in a vacuum. This one of the best pieces of evidence proving that the visual record of the Apollo moonwalks was actually shot in an airless environment.



Figure 3.11-2. Apollo 16's Rover kicks up dust, which exhibits an unusual behavior. Detail from a 16 mm movie film frame.



Figure 3.11-3. 16 mm footage of Apollo 16's Rover.

This unusual behavior of the lunar dust also occurs on a smaller scale when the astronauts walk. At every step, the dust they strike with their boots fans out and falls sharply to the ground.

This effect is especially conspicuous in backlit TV and film footage of the Moon missions and can be glimpsed even in the footage of Apollo 11, the first lunar landing, as shown in Figure 3.11-4.

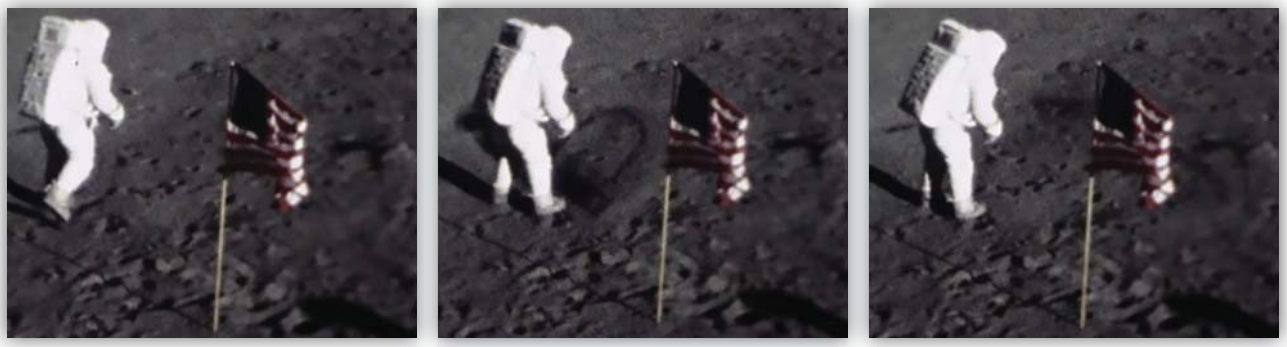


Figure 3.11-4. Detail from three successive frames of the 16 mm color film footage of Apollo 11's moonwalk: Buzz Aldrin demonstrates the fanning and sharp fall of moondust as part of a series of experiments on the behavior of lunar soil.



http://tiny.cc/1w5mbz



http://tiny.cc/5x5mbz



http://tiny.cc/vy5mbz

Figure 3.11-5. TV and film recordings of moonwalks clearly show the behavior of moondust.



Figure 3.11-6. The Apollo 11 landing in a frame from the 16 mm color movie footage.

While this effect can be rather difficult to perceive in still images, it is very clear in movies and TV recordings. Here are some examples.
The weird behavior of the dust is also eloquent in the Moon landing footage. When the Lunar Module is about to touch the ground, the dust scatters horizontally in straight lines, propelled by the LM's rocket exhaust, forming a thin, shallow mist that hides the details of the surface. As soon as the rocket motor shuts down, the dust settles suddenly, without billowing at all, and the ground becomes abruptly visible again.

How could all this have been achieved with the special effects technology of the 1960s?

Some hoax proponents have suggested the use of heavy, coarse sand, but nobody so far has been able to show that such sand actually behaves like the dust in the Apollo footage. It's not just a matter of falling sharply without forming clouds: it also has to change the way it reflects the light when it is kicked up, becoming very dark in some lighting conditions and extremely bright in others, as occurs in the Moon mission television recordings and movies.

Another approach might have been to shoot footage of model spacecraft inside a vacuum chamber. NASA researchers

actually used such a chamber to study how moondust would move when affected by a rocket motor blast in a vacuum: they were concerned that the descent motor would kick up so much dust that the crew would lose the ability to see.

However, this method would have worked only for footage of the spacecraft. Any TV or film which showed moving astronauts, whose motions could not be reproduced by a scale model or a puppet, would have entailed placing an entire soundstage in vacuum, including the full-size astronaut actors, movie cameras, TV cameras, lights and stagehands.

This would have required a truly immense vacuum chamber, since some Apollo footage shows the astronauts and their electric car walking or driving uninterruptedly for hundreds



Figure 3.11-7. Researchers observing a moon dust simulation inside a small vacuum chamber at the Lewis Research Center in 1960. Photo C-1960-53766 (cropped). Source: NASA/Glenn Research Center.

of meters (yards). But even today, the world's largest vacuum chamber, located at Plum Brook Station in Ohio, is only 30 meters (100 feet) in diameter. The Lunar Module alone would have filled one third of this chamber, leaving little room to walk around it.

Moreover, this special effect would have to be produced flawlessly *at the same time as all the others*, and for long, uninterrupted sequences. Again, it would have been easier and safer to actually go to the Moon.





http://tiny.cc/825mbz

Figure 3.11-8. A Moon landing as depicted in 2001: A Space Odyssey *(1968). Credit: MGM.*

It's interesting to compare the Apollo lunar landing footage with the Moon landing shown in *2001: A Space Odyssey*, a movie that at that time of its release in 1968 was the peerless state of the art in visual effects. The movie was directed by Stanley Kubrick, who is often mentioned by hoax proponents as the visual effects master who allegedly faked Apollo's photographs, television broadcasts and film footage.

It turns out that the behavior of the dust in *2001* is hopelessly wrong: it floats and forms swirling eddies, as shown in Figure 3.11-7. This means that the scene was shot in an atmosphere, not in a vacuum.

If this is the absolute best that could be achieved with the special effects technology of the 1960s, how did NASA fake the Moon footage?

3.12 The size of the alleged soundstage

People who claim that the Moon mission footage was produced on a movie set often fail to consider that many Apollo photos were taken in sequences while the astronaut-photographer slowly turned around. Therefore, these pictures can be assembled into huge panoramic images, as shown in Figure 3.12-1 for the Apollo 11 mission.



Figure 3.12-1. Composite image based on a sequence of photographs taken by Neil Armstrong during Apollo 11 (AS11-40-5930/31/32/33/34/39/40). Credit: Moonpans.com.

Achieving the same result with special effects would have required a colossal soundstage. The movie set, moreover, would have had to be lit entirely by a single, high-power light source, because multiple lights would have produced multiple shadows.

There's more. The Apollo missions that carried the Rover Moon car brought back footage from the onboard movie camera that shows the Rover traversing the lunar surface in uninterrupted sequences that last tens of minutes. For example, the color film footage known as *Traverse to Station 4* from the Apollo 16 mission lasts *25 minutes* without breaks (these long durations were achieved by using low frame rates).

This footage shows the changing surroundings and terrain under the Rover's wheels, which kick up dust that falls sharply to the ground.



Figure 3.12-2. John Young and Charlie Duke (Apollo 16) walk from the Rover towards the boulder nicknamed House Rock*, 220 meters (720 feet) away.*

Achieving this effect by using Hollywood-style tricks would have required a colossal movie set, and since the Rover is seen kicking up fine dust that falls right back to the ground as it travels instead of forming a cloud, that giant movie set would have to be entirely in a vacuum. All this would have to be lit by a single light source.

Hoax proponents might suggest a highly sophisticated scale model of the Rover and of the lunar surface, placed in a manageably smaller vacuum chamber. But that would not explain uninterrupted video sequences such as the one in Figure 3.12-2, taken from the live television broadcast of the Apollo 16 mission: it shows astronauts (impossible to simulate with models) walking continuously away from the camera until they almost disappear from sight, despite the camera zooming in, without ever reaching the far end of the alleged movie set.

It is important to bear in mind that on the Moon there's no atmospheric haze to blur the details of distant objects and provides a visual hint of distance and size. There are no familiar references, such as trees or houses, that can provide a sense of scale. Indeed, the rock that appears to be just behind the astronauts as they walk towards it turns out to be as tall as a four-story building (hence the name *House Rock*): as detailed in NASA's *Apollo 16 Preliminary Science Report*[7], it is 12 meters (40 feet) tall, measures 16 meters by 20 (50 by 65 feet) at its base, and lies 220 meters (720 feet) from the television camera, which is mounted on the Rover.

7
[http://tiny.cc/q6ehoz]

It is really hard to imagine a colossal secret movie set, lit perfectly by a single light source, of such gigantic size as to allow such a long, uninterrupted walk and *placed entirely in a vacuum*.

For those who speculate that the Moon pictures were faked using painted backdrops to simulate the distant horizon, it should be noted that many Apollo photographs were taken as *stereo pairs* (by taking a first picture and then shifting the camera slightly sideways). These stereo pairs can be

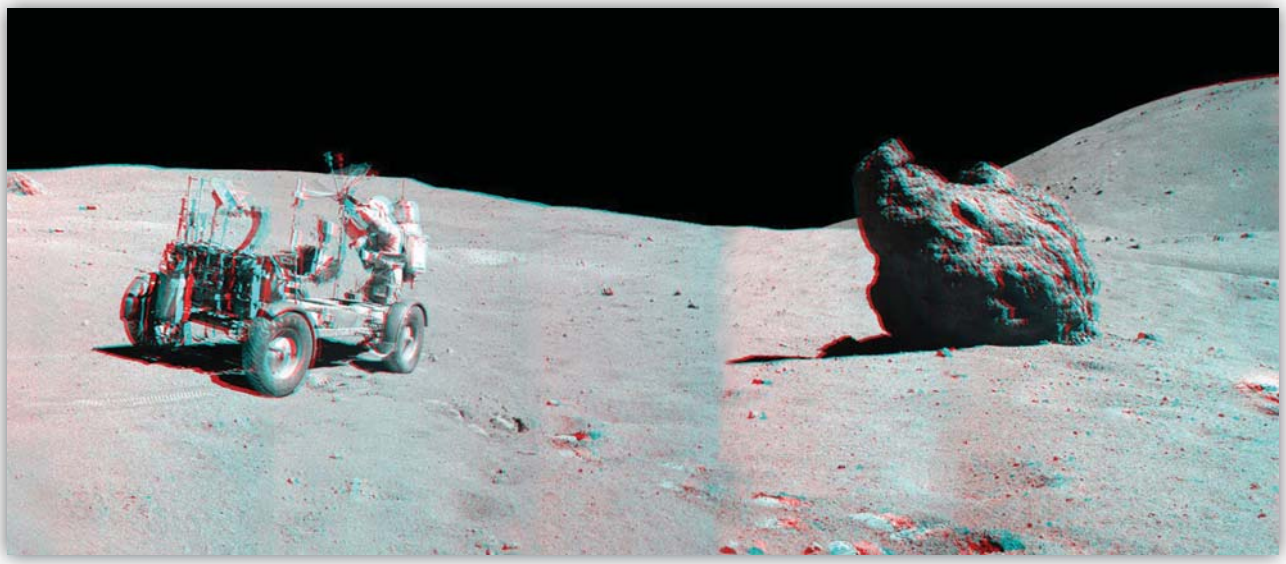


Figure 3.12-3. Detail of a stereoscopic panorama created by Roberto Beltramini starting from photographs of the Apollo 16 mission. To view it in 3D you need red-blue glasses. Source: Apollo 16 Image Library.

assembled digitally to produce 3D images or *anaglyphs* that clearly reveal the actual depth of the scene.

Several collections of these 3D photographs are available in NASA's *Apollo Anaglyph Albums*[8] and in the book *Luna mai vista (Unseen Moon)* by Roberto Beltramini and Luigi Pizzimenti. They can be viewed with glasses fitted with red-blue filters. The original picture pairs can also be edited by anyone to create a stereogram for glasses-free 3D viewing in color.

8 [http://tiny.cc/g8ehoz]

For example, the following 3D image, created by Erik van Meijgaarden from Apollo 17 photos, shows the Lunar Rover

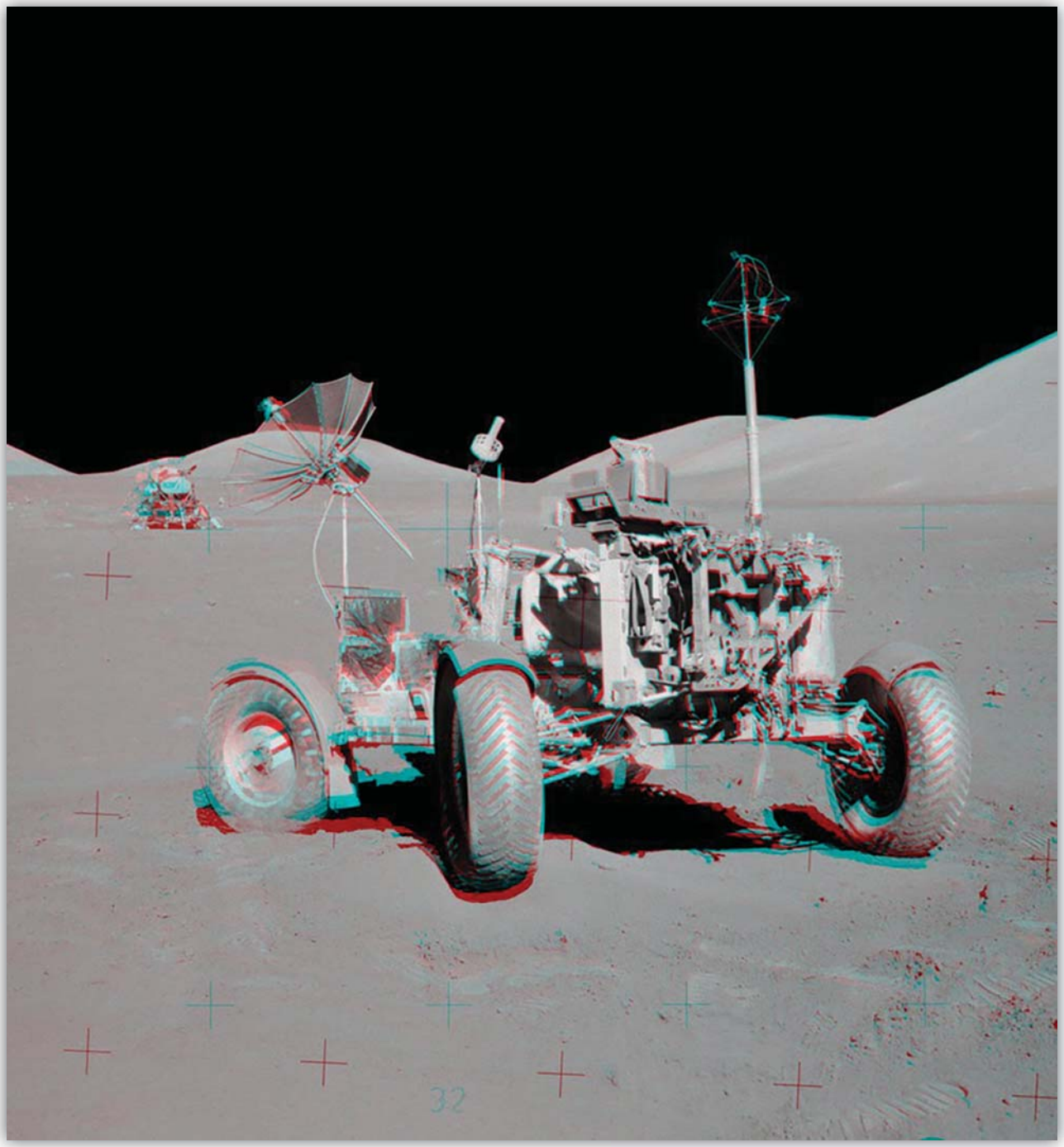


Figure 3.12-4. Anaglyph of the Apollo 17 "VIP Site". Credit: Erik van Meijgaarden.

car in the foreground, at the so-called *VIP Site* where it was placed to televise the liftoff of the astronauts in the Lunar Module. The LM is in the background on the left.

If you look at this images with red-blue glasses, it becomes evident that the LM is quite far away and that the hills and mountains are even farther away. Achieving this effect on a 1960s movie set would have been impossible.

3.13 The Moon walk proves the moonwalks

People who allege that the visual record of the Apollo missions was faked frequently claim that the astronauts' gait on the Moon was simulated by using wires or slow motion or both.



Figure 3.13-1. Mythbusters *tries to simulate the astronauts' gait by using wires and slow motion, and fails. Credit: Discovery Channel.*

In 2008, Discovery Channel's *Mythbusters* show put this claim to the test. Adam Savage, one of the show's hosts, donned a spacesuit replica and tried to simulate the lunar walk by slowing down the recording of his strides and by using a special harness that supported five sixths of his weight, simulating the Moon's low gravity, which is one sixth of the Earth's.

Both methods failed miserably. Direct comparison between the Apollo footage and the effect of wires and slow motion reveals glaring differences. The harness and wires reduce the effect of gravity on the fake astronaut's *body*, but not on the items he is wearing or carrying, which dangle and swing under full Earth gravity, giving away the trick.

Slow motion instead slows *all* of the simulated astronaut's movements, whereas the Apollo footage shows that the astronauts made quick arm, leg and hand motions as they walked on the Moon. Achieving this effect through slow motion would have required the fake astronauts to move impossibly fast so that their gestures would appear normal when slowed down.

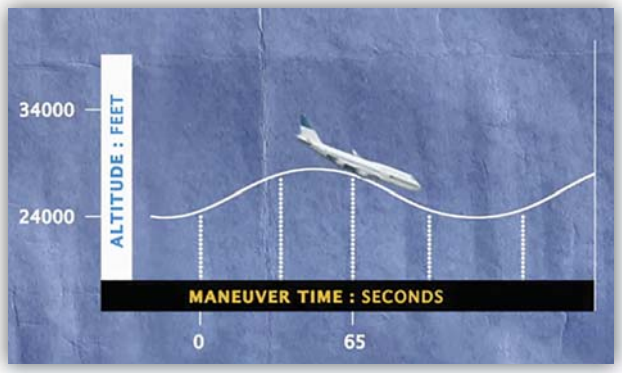


Figure 3.13-2. The Vomit Comet's trajectory as described by Mythbusters*. Credit: Discovery Channel.*

There's only one way to achieve on Earth the fluid motions of the astronauts and the slow oscillation of the items they carry that we see in the Apollo footage: flying in a special aircraft which traces rollercoaster-like parabolic arcs. Not unsurprisingly, the aircraft is known as *Vomit Comet*.

By adjusting the aircraft's speed and inclination appropriately, these arcs create brief periods during which the cabin conditions are equivalent to lunar gravity, just like a car driving at speed over a hill makes its occupants "float" for an instant. The effect is the best approximation of the zero- or low-gravity conditions of spaceflight. Indeed, this is how Apollo astronauts trained for their spacewalks and moonwalks. The same technique was used for some of the zero-gravity shots in Ron Howard's great



Figure 3.13-3. Mythbusters*' Adam Savage moonwalks in simulated one-sixth gravity in the padded cabin of the Vomit Comet. Credit: Discovery Channel.*

movie *Apollo 13* and is still used today to train current astronauts.

Mythbusters performed flights that used this method and obtained footage showing a very smooth gait that exactly matches the Apollo moonwalk footage without resorting to wires or slow motion.

One might wonder whether this method could have been used to shoot fake moonwalks in the 1960s, but there's a catch: the low-gravity effect produced in this way only lasts a few seconds at a time. Moreover, it occurs within the cramped space of an aircraft cabin. The Apollo footage instead includes uninterrupted hour-long shots taken in very large spaces.

Also, we've seen that the visual record of the Moon missions shows phenomena that can only occur in a vacuum, such as the behavior of the dust. The cabin, therefore, would have to be a colossal top-secret flying vacuum chamber capable of hour-long parabolic arcs. Once again, flying to the Moon would have been easier.

Shooting fake Moon footage underwater might also be considered. Carefully adjusting the buoyancy of every single item carried and worn by the astronauts could provide a credible visual appearance of low gravity. However, this technique would require an immense and very deep tank filled with crystal-clear water, and a single stray bubble would reveal the fakery. Besides, in an underwater environment the simulated moondust would not fall back suddenly as it does in the Apollo footage: it would tend to float and swirl about, once again giving away the trick.

Indeed, the key problem of faking the Apollo moonwalk footage isn't achieving a single visual effect, but *achieving them all simultaneously* and for long, unbroken sequences, which must all be perfectly consistent, because the TV footage must match the film footage and both must match the photos.

In a nutshell: in the 1960s, the only way to obtain footage of astronauts walking on the Moon as shown by the Apollo visual record was to actually go to the Moon.

And if the Apollo footage is authentic, so are the Moon landings.

3.14 Attempted simulations in movies

Even the best visual effects of today often fail to recreate authentically and simultaneously all the physical phenomena observed in the original Apollo lunar footage.

For example, Michael Bay's blockbuster *Transformers - Dark of the Moon* (2011), in which the Apollo 11 mission plays a key part and is reconstructed extensively, gets the lunar dust wrong: Neil Armstrong's first step kicks up a cloud of dust, revealing that the scene was not shot in vacuum.

The TV series *From the Earth to the Moon* (1998), produced by Tom Hanks, Ron Howard and Brian Grazer, is considered one of the most accurate reconstructions of the moonwalks, which were simulated in a huge soundstage by attaching large helium-filled balloons to a harness inside the spacesuits, so as to give the astronaut-actors a visual buoyancy similar to lunar gravity.

The sharply outlined shadows of the original Apollo images were obtained by lighting the entire set with a single light source: a 2-meter (6-foot) convex mirror onto which twenty of the most powerful spotlights available in the film business projected their beams. The production even featured an original lunar module, a leftover of the canceled Apollo 18, 19 and 20 missions. Yet despite these amazing efforts, the beautiful visual effects sequences of the show lack other phenomena, such as the correct behavior of lunar dust as the astronauts walk.

The IMAX documentary *Magnificent Desolation: Walking on the Moon 3D* (2005), also featuring Tom Hanks among its producers, finally got the moondust right and also solved the challenge of camera and set reflections in the mirror-finished



Figure 3.14-1. A still from Transformers 3 *reveals a mistake in the special effects: the moondust billows instead of falling in arcs, as it should in a vacuum. Credit: Paramount Pictures.*



Figure 3.14-2. Digitally generated moondust being kicked up by an astronaut in Magnificent Desolation: Walking on the Moon 3D*. Credit: IMAX Corporation.*

spacesuit helmet visors. However, these feats were achieved by resorting to digital visual effects, which were not available in 1969.

3.15 An impossible feat

In summary, here's the best evidence that the Moon missions were authentic:

- vast amounts of publicly available documentation, which can be cross-checked and has been validated by experts from all over the world for decades
- highly complex and perfectly realistic radio and television signals
- not a single confession or leak over decades
- no objections by the rival Soviet regime
- direct reception of voice communications from the Moon by professional and amateur radio astronomers
- no objections by any expert in spaceflight, astronomy, astrophysics, radio communications or any other relevant field
- carefully selected Moon rocks returned to Earth
- reflectors placed on the Moon, which can be checked even today
- recent photographs of the Apollo vehicles and instruments left on the Moon, which are consistent with the decades-old NASA documents of the lunar missions
- pictures that could only be taken in the presence of an astronaut on the Moon and have been confirmed independently by non-US space missions
- dust that behaves in the Apollo footage in a way that is possible only in a vacuum
- astronauts walking in a way that is possible only in one-sixth gravity.

In view of all these facts, the inescapable conclusion is that the Moon hoax theorists are right about the Moon landings in one respect: it's true, as they often say, that the technology of the 1960s was not up to the challenge.

The challenge of faking them.

4 Moon hoax beliefs and believers

You might wonder whether the many Moon hoax conspiracy theories are really worth debunking in detail, especially after reading the previous chapter. It's easy to think of these theories as the delusions of a small bunch of oddballs or as the concoctions of peddlers of ultimate truths seeking followers who are easily parted from their money.

But Moon hoax theories and doubts about the Moon landings are widespread in public opinion. Try an informal poll among your friends and relatives and you'll notice this, especially in younger people. Modern cynicism and distrust of government, the passage of time and the gradual passing of the living witnesses of the Apollo missions will increase the appeal of conspiracy theories if nothing is done to expose their fallacies. These are the same processes that, on a very different level, feed Holocaust denial.

Besides, dealing with these claims is an excellent opportunity to retell the fascinating story of the Moon missions in a way that's not pedantic but often lively and sometimes truly amusing.

4.1 How many people believe these theories?

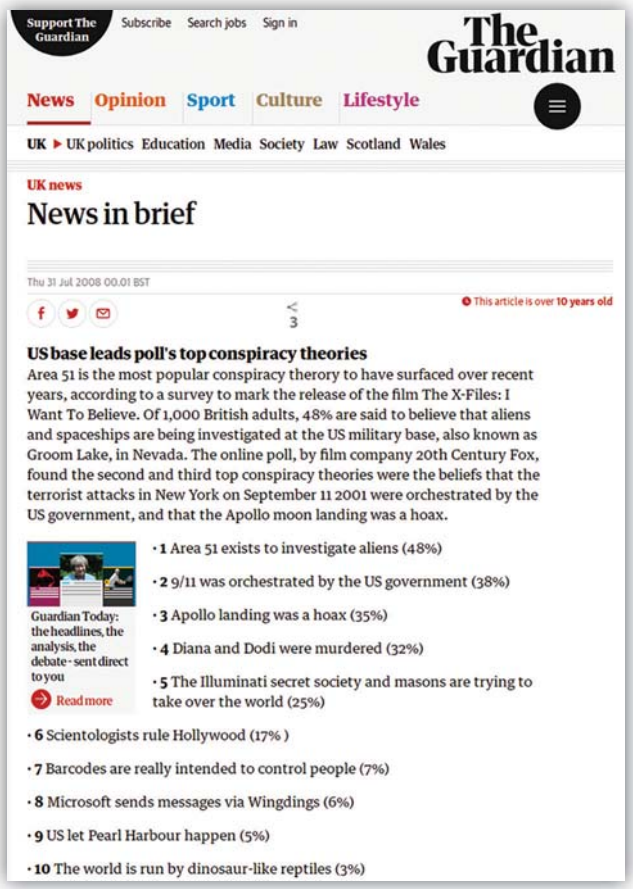
Between 1995 and 2013, the percentage of American adults who believe that the Moon landings were faked in some way has remained stable around 6%.

- In 1995, a Time/CNN/Yankelovich Partners, Inc. poll found that 6% of Americans believed that *"the government staged or faked the Apollo Moon landing"*, whereas 83% disagreed and 11% said they had no opinion.
- A similar Gallup poll taken in 1999 indicated the same 6% figure, but with 89% disagreeing and 5% having no opinion.
- A 2001 Zogby poll yielded essentially similar results: 7% hoax believers, 87% convinced that the Moon landings were real and 4% not sure.
- Public Policy Polling found similar results in a 2013 US voter poll: 7% supported the claims of fakery, 9% were not sure and 84% said they believed the Moon landings were real.[1]

1 *Landing a Man on the Moon: The Public's View,* by Frank Newport, Gallup.com, 1999*; As Seen on This Morning's NBC Today Show: Truth or conspiracy: Lunar landing – Did the mission to the Moon really get off the ground?,* Zogby.com, 2001*; Democrats and Republicans differ on conspiracy theory beliefs,* PublicPolicyPolling.com, 2 April 2013.

Six or seven percent might seem a small figure, and Gallup explains that the margin of error in its poll was 3%, adding that *"it is not unusual to find about that many people in the typical poll agreeing with almost any question that is asked of them"*, but even so it means that several million Americans believe Moon hoax theories.

Moreover, the figure is considerably higher in a specific age group: young people. A poll taken in 2006 by Dittmar Associates among young American adults indicated that 27% expressed some doubt that NASA went to the Moon, with 10% of the overall sample indicating that it was *"highly unlikely"* that a crewed Moon landing had ever taken place. The Zogby poll mentioned earlier concurs, noting that *"fewer 18-29 year olds than any other age group believe the Moon landing occurred"*.[2]



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US base leads poll's top conspiracy theories

Area 51 is the most popular conspiracy therory to have surfaced over recent years, according to a survey to mark the release of the film The X-Files: I Want To Believe. Of 1,000 British adults, 48% are said to believe that aliens and spaceships are being investigated at the US military base, also known as Groom Lake, in Nevada. The online poll, by film company 20th Century Fox, found the second and third top conspiracy theories were the beliefs that the terrorist attacks in New York on September 11 2001 were orchestrated by the US government, and that the Apollo moon landing was a hoax.

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- **1** Area 51 exists to investigate aliens (48%)
- **2** 9/11 was orchestrated by the US government (38%)
- **3** Apollo landing was a hoax (35%)
- **4** Diana and Dodi were murdered (32%)
- **5** The Illuminati secret society and masons are trying to take over the world (25%)
- **6** Scientologists rule Hollywood (17%)
- **7** Barcodes are really intended to control people (7%)
- **8** Microsoft sends messages via Wingdings (6%)
- **9** US let Pearl Harbour happen (5%)
- **10** The world is run by dinosaur-like reptiles (3%)

Figure 4.1-1. The results of a 2008 UK poll on conspiracy theory beliefs. Note the 7% of participants who believe that barcodes are a secret method for controlling people.

Informal polls in other countries suggest highly variable percentages of hoax believers. In the United Kingdom, a 2008 Internet poll on a sample of 1000 people, arranged by 20th Century Fox for the launch of the movie *X-Files: I Want to Believe,* indicated that 35% of the participants thought the Moon landings were faked. A 2009 survey yielded an estimate of 25%.[3]

In Germany, an Internet poll launched in 2001 by *Der Spiegel* magazine reported that 47% of the participants agree with hoax theories. Other similar surveys suggest hoax theory support at 44-62% of participants in France, 40% in Sweden, and 49% in Russia.[4]

However, these polls are not based on a statistically representative sampling of the population, but rely on volunteer participation, and since hoax theory supporters tend to be rather active in spreading their beliefs these percentages should be considered with a degree of caution.

Moon hoax belief also has significant political overtones. Admitting that Americans landed on the Moon entails acknowledging their technological superiority, and some ideologically-driven people and regimes aren't very keen to do so.

For example, space historian and journalist James Oberg noted in 2003 that *"many Cuban schools, both in Cuba and*

2 *Engaging the 18-25 Generation: Educational Outreach, Interactive Technologies, and Space*, Mary Lynne Dittmar, in *AIAA* 2006-7303 (American Institute of Aeronautics and Astronautics).

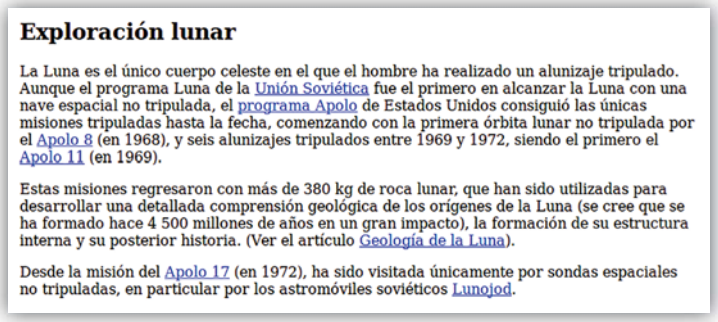
3 *US Base Leads Poll's Top Conspiracy Theories,* in *The Guardian*, July 31, 2008; *Britons Question Apollo 11 Moon Landings, Survey Reveals*, in *E&T Magazine*, 2009.

4 *Ein kosmischer Streit* in *Der Spiegel*; *20min.ch* and *Pourourcontre.com*; *Aftonbladet.se*; *Cnews.ru*; polls surveyed in June 2013.

where Cuban schoolteachers were loaned, such as Sandinista Nicaragua, taught their students that Apollo was a fraud".[5]

5 *Lessons of the "Fake Moon Flight" Myth,*in *Skeptical Enquirer,* March/ April 2003; *Getting Apollo 11 Right*, ABC News, 1999.

It should be noted, however, that Oberg based his claim on just three anecdotal reports and that Moon landing denial does not appear to be the current position of the Cuban government, at least according to the official Ecured.cu encyclopedia.



Exploración lunar

La Luna es el único cuerpo celeste en el que el hombre ha realizado un alunizaje tripulado. Aunque el programa Luna de la Unión Soviética fue el primero en alcanzar la Luna con una nave espacial no tripulada, el programa Apolo de Estados Unidos consiguió las únicas misiones tripuladas hasta la fecha, comenzando con la primera órbita lunar no tripulada por el Apolo 8 (en 1968), y seis alunizajes tripulados entre 1969 y 1972, siendo el primero el Apolo 11 (en 1969).

Estas misiones regresaron con más de 380 kg de roca lunar, que han sido utilizadas para desarrollar una detallada comprensión geológica de los orígenes de la Luna (se cree que se ha formado hace 4 500 millones de años en un gran impacto), la formación de su estructura interna y su posterior historia. (Ver el artículo Geología de la Luna).

Desde la misión del Apolo 17 (en 1972), ha sido visitada únicamente por sondas espaciales no tripuladas, en particular por los astromóviles soviéticos Lunojod.

Figure 4.1-2. An excerpt from Cuba's official encyclopedia, Ecured.ru, which describes the Apollo Moon landings in detail.

When British documentary film maker Sean Langan was kidnapped by the Taliban in the Afghanistan-Pakistan border region in 2008, *"during his three-month ordeal he was interrogated by his captors many times and he was often surprised by what they wanted him to confess to. One subject they kept returning to were the Moon landings. They refused to believe that America had put men on the Moon and, again and again, they tried to browbeat him into admitting that NASA's programme of manned space flight had been an elaborate hoax".*[6]

6 *Obama's cancellation of moon landings is a case of 'No we can't', not 'Yes we can'*, by Toby Young, *The Telegraph*, 2010.

Anti-Americanism is a significant driving force behind lunar conspiracy claims, like it is for theories regarding the 9/11 attacks and UFOs, even in some moderate countries where popular resentment against US government policies is widespread. Within the United States, this resentment takes the form of a specific distrust of the federal government and of authorities in general, as clearly shown by the writings of Bill Kaysing, Ralph Rene and many other Moon hoax theorists.

4.2 Healthy doubt versus misinformed paranoia

People who have no doubts that the Moon landings really happened often make the mistake of thinking that hoax theorists are all stupid and paranoid. This misconception is a frequent cause of embarrassment when it turns out that people whom they hold otherwise in high esteem are doubters or conspiracy believers.

Unquestionably, some of the hoax theory supporters are very paranoid: they believe not only in the Moon hoax but also in the many other conspiracy theories that are especially abundant on the Internet, such as "chemtrails", 9/11, the Kennedy assassination, earthquakes controlled by the US military, alternative medical treatments suppressed by multinational pharmaceutical companies, contacts with extraterrestrials covered up by the world's governments and all sorts of secret power cliques, from "international banking cartels" (a euphemism for Jews) to the Illuminati and the Reptilians.

However, not everyone who leans towards alternative theories regarding the Moon missions is like that. Many people are simply misinformed or not informed at all: they have only seen some of the many Internet sites and TV programs that support the Moon hoax theories and are unaware of the immense amount of information and evidence that debunks them. Part of the reason is that most of the in-depth evidence is only available in highly technical jargon.

There's nothing stupid or paranoid in being seduced by the powerful, professionally packaged images of a biased television show designed to grab attention at any cost. We're naturally inclined to assume that what we see in a documentary or a book is true and authoritative because it's backed by a publisher or a national radio or TV network and it's labeled as journalism. Sadly, that's not always true.

There's also nothing wrong in questioning any officially dispensed truth, at least until it is corroborated by reliable independent sources. After all, governments do lie and conspire, as was shown at the time of the Apollo flights by the Watergate scandal and the misinformation about the war in Vietnam.

The difference between a poorly informed or misinformed person who has doubts and a hardcore conspiracy theorist is very simple. The doubter, after being presented with all the facts, realizes that he or she has been misled and accepts those facts; the conspiracy theorist will deny the evidence, hold on to some trivial unexplained detail as if it were definitive evidence of the hoax, and often accuse those who

argue that the Moon landings were real of being "sheeple" or paid shills of America or of the hidden forces that organized the conspiracy.

This kind of language is not an exaggeration: that's actually what many Moon hoax believers says about me in their publications and personal emails to me.

Basically, a Moon hoax believer is someone who after being shown that two plus two is four, keeps on arguing that it's actually five. Spending time in a debate with such people is therefore pointless. It is instead time well spent with doubters, who will often be grateful after seeing all the evidence that has dispelled their doubts. So if you decide to debate, choose your sparring partner wisely, and refer to the tips in Chapter 12.

4.3 Wide but shallow media coverage

One of the reasons why some people have been taken in by Moon hoax theories is that the media coverage during the Apollo missions was vast but nonetheless surprisingly shallow if compared to today's drinking-from-a-fire-hose standards.

In the Sixties and Seventies it was very complicated and prohibitively expensive for an ordinary person, especially outside the United States, to go beyond what was offered by the media and obtain copies of NASA's technical reports or of a complete, high-resolution series of the photographs taken on the Moon, which would have to be printed or microfilmed and mailed.

The only sources of readily available information were the press and the radio and TV networks: most people got only what these sources deemed fit to broadcast or publish, which rarely included technical minutiae. Astronomy and aviation magazines provided more detail, but they were read only by enthusiasts; the general public didn't get that kind of in-depth information. Today, instead, thousands of pages of original, complete technical reports and tens of thousands of Apollo photographs are just a click away on the Internet.

Information regarding the Moon flights was also politically sensitive and therefore subject to control, not necessarily as censorship by government order but as self-censorship of news organizations, which often chose to promote America's image of technical prowess and declined to publish unsavory details that would spoil it and damage the political competition with the Soviets on the world's highly volatile stage.

The end result was a widespread but false impression of magically flawless missions, on which Moon hoax theorists often prey. At the time, only the people who were closely involved in the Moon missions knew otherwise. Today, now that the Cold War is essentially over and many confidential files (such as spy satellite photographs of the Soviet N1 lunar booster) have been released by the US and Russian governments, everyone can find out how things actually went. It's a fascinating journey of discovery even for non-doubters.


Lo straordinario racconto dell'impresa alle pagine 8 e 9

Il Messaggero

Minuto per minuto la passeggiata lunare

LUNA

Ha vinto l'uomo

PRIMO PASSO

Figure 4.3-1. The front page of Italian newspaper Il Messaggero, July 21, 1969, designed by graphic artist Piergiorgio Maoloni. Notice the fake lunar bootprint made with a fishing boot.

This dearth of material to show and the highly technical nature of the subject sometimes led the media to publish their own little Moon hoaxes. For example, for Apollo 11's first Moon landing, the front page of Italian newspaper *Il Messaggero* of July 21, 1969 (Figure 4.3-1) was noted by *Time* magazine, and is currently featured in the Kennedy Space Center exhibition, for spectacularly covering three-quarters of its front page with three words: *"Luna – Primo Passo"* (*"Moon – first step"*). But since the now-famous photograph of Buzz Aldrin's bootprint was not available at the time (it was still undeveloped in a Hasselblad film magazine on the Moon), the newspaper nonchalantly faked it by using the print of an ordinary fishing boot.

Of the thousands of photographs that were taken, the general public only got to see the small set chosen and published by newspapers and magazines or issued by NASA, and even those images suffered from several analog transfers and heavy-handed manual retouching that eroded the quality and sharp detail of the originals, as shown by Figures 4.3-2 and 4.3-3.

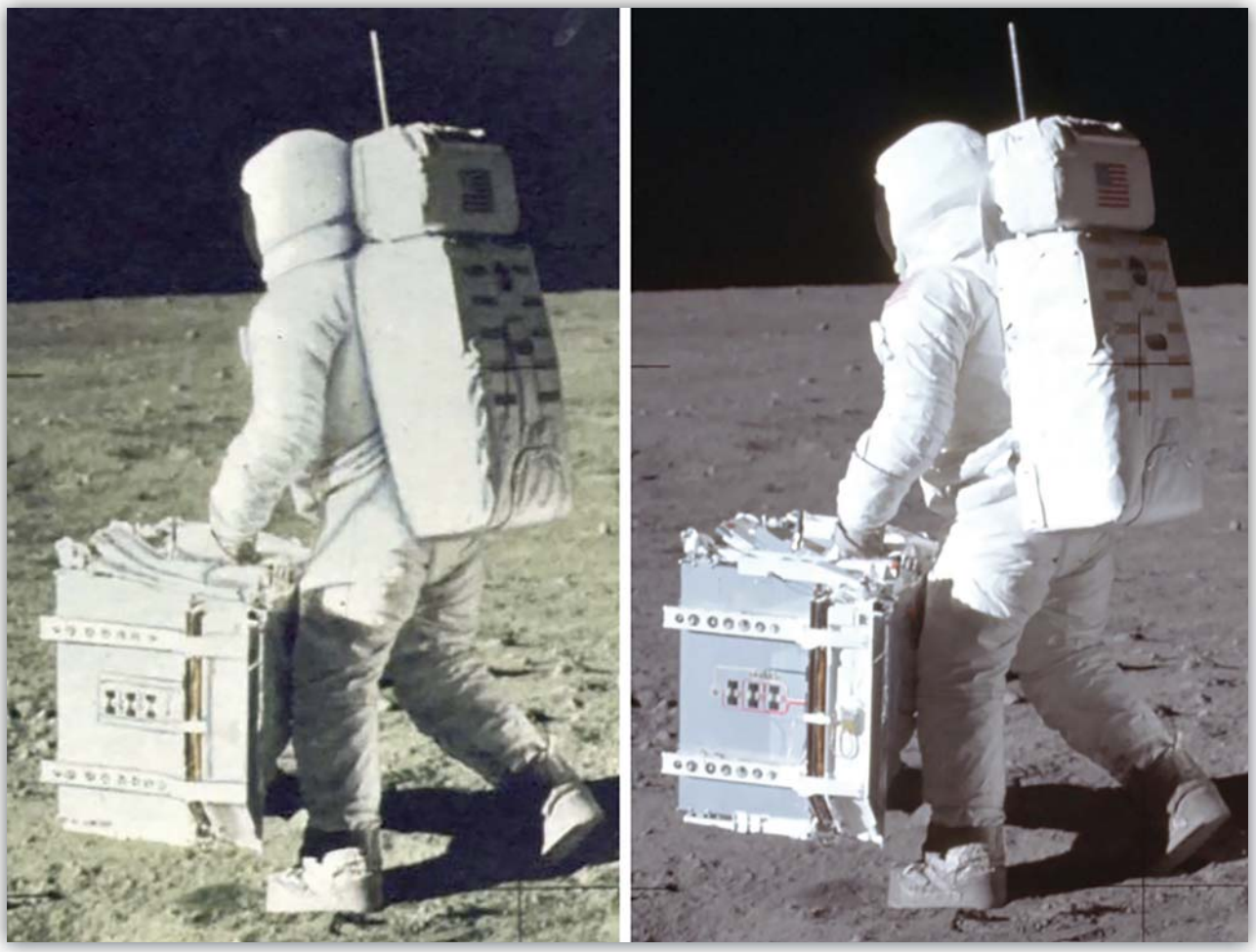


Figure 4.3-2. Left: a detail of NASA photo AS11-40-5945 (Buzz Aldrin on the Moon during Apollo 11) as published in September 1969 in the Italian hardcover book Terra Luna Anno 1 *(published by Mondadori). Right: the same detail in a direct scan of the original film.*

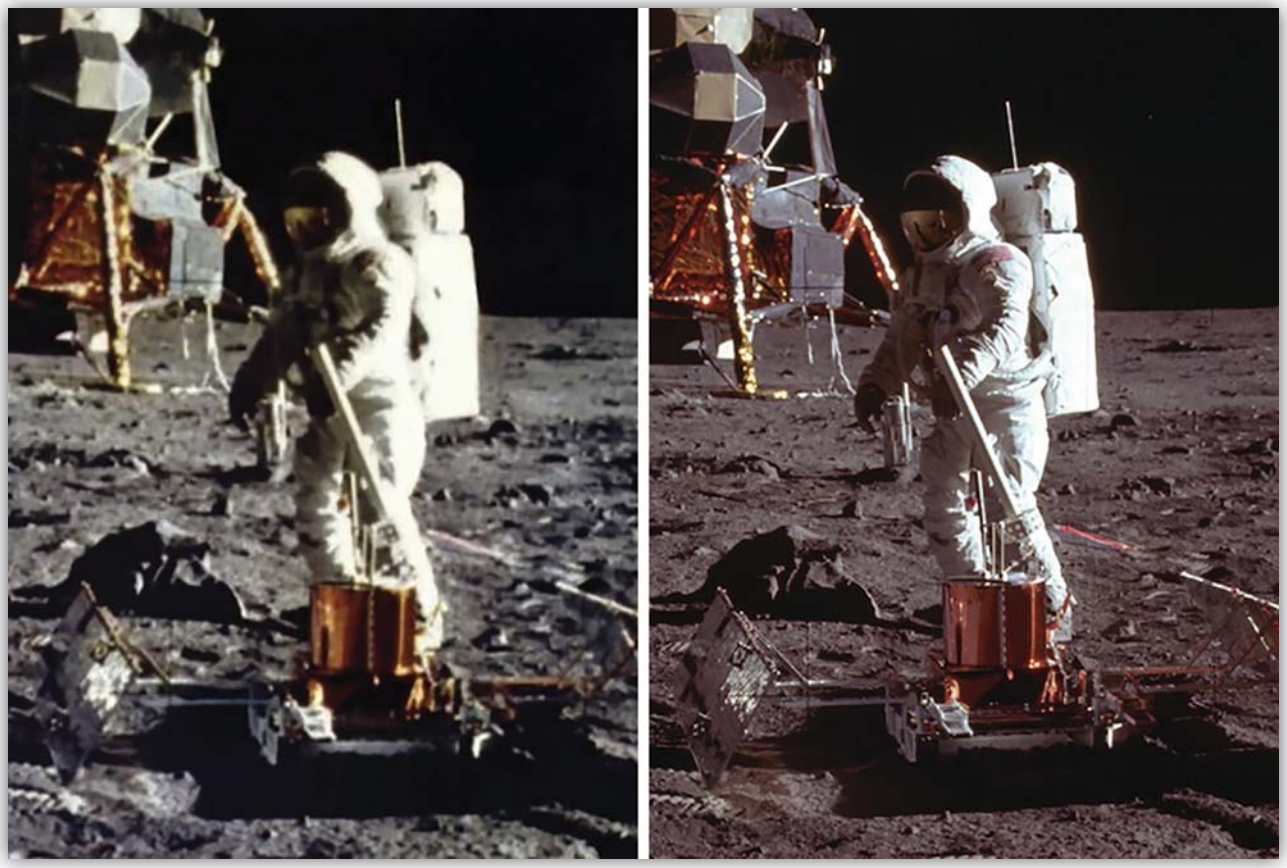


Figure 4.3-3. Left: a scan of an original 1975 NASA print of photo AS11-40-5949 (cropped) showing Buzz Aldrin on the Moon during the Apollo 11 mission. Right: a scan of the same photo taken directly from the original film and now downloadable from NASA's website.

The color film and television recordings were available only when they were broadcast by the TV networks or shown in movie theaters, often in the form of faded, grainy, low-quality transfers that don't do justice to the actual clarity and definition of the originals.

Today, instead, anyone can buy DVDs and Blu-ray discs with direct digital scans and transfers of the entire Apollo visual record and view the original detail and the pictures that the media, at the time of the Moon landings, didn't show due to inevitable space and time constraints.

The complete recordings of the radio transmissions of all the missions are also available to download. Even the audio and transcripts of Apollo 11's onboard voice recorders are now online in NASA's archives and at Live365.com.

Rather paradoxically, we have a far more complete and detailed coverage of the Moon landings today than we had while they were taking place.

4.4 Media misdirection

From today's privileged viewpoint of free Internet access to the entire archive of Moon landing photographs, video and film footage and technical documentation, anywhere and anytime, it's easy to forget that there were no live TV transmissions from the Apollo spacecraft during the lunar module's descent to the surface of the Moon, so most media outlets covered the first Moon landing by showing artist's renderings of the event.

For Walter Cronkite's famous live TV coverage of the Apollo 11 landing, CBS showed a rather crude animation which was timed to match the scheduled timetable of the landing but went confusingly out of sync when Neil Armstrong delayed the actual touchdown to find a safe landing spot. Cronkite, however, correctly announced *"We're home. Man on the Moon!"* and exclaimed his famous *"Oh, boy!"* after Armstrong had radioed that the LM had landed.

These renderings and animations were dramatically effective but often quite inaccurate in their artistic license and created misleading expectations in the public. For example, they almost invariably depicted visible stars and a bright, fiery exhaust plume from the LM's descent engine, although in actual fact the stars would be too faint to see against the glare of the daylit lunar surface, and the LM engine plume was colorless and essentially invisible in the vacuum of space.



Figure 4.4-1. Recording of the CBS live coverage of the Apollo 11 landing, showing the animation used to describe the events [http://tiny.cc/7g7ooz].

Aesthetics took precedence over scientific accuracy, and the visible exhaust was also a very convenient visual shorthand to explain how the spidery spacecraft could fly and hover in a vacuum. The same inaccuracy occurs in many NASA illustrations.

Moreover, the quality of the images published at the time by many newspapers and magazines was misleading. TV screenshots were blurry, with very few details. Film footage lost its sharpness during transfer to TV recording formats. Photographs fared better, but were still severely degraded by many steps of analog duplication, which lost details and exaggerated contrast. All this was fertile ground for anyone who wanted to argue that the images were fake and that the blur hid wires or other special effects.

4.5 A truly unbelievable journey



Figure 4.5-1. A British Hawker Hurricane propeller-driven fighter used during World War II, photographed in 2005. Source: Wikipedia.

Other extenuating circumstances must also be considered when looking back at the birth of Moon hoax theories. The space age had begun only *twelve years earlier*: Sputnik, the world's first artificial satellite, had been launched in 1957. The first human space flight had occurred in 1961, yet just eight years later mankind was walking on the Moon. Many people simply didn't have the time to get accustomed to the reality of spaceflight.



Figure 4.5-2. A British de Havilland Comet *jet airliner at Entebbe airport, in Uganda, in 1952. Photo TR6113, UK Ministry of Information/Imperial War Museum.*

Things were changing at a dazzling, unbelievable rate. Less than ten years after the end of the Second World War, which had been fought with propeller-driven planes, well-heeled civilians were already flying around the globe in jet airliners: the de Havilland *Comet* had entered service in 1952. Two years later, in 1954, engineers began designing a *supersonic* airliner, *Concorde*.

Moreover, until Apollo 8 flew around the Moon in 1968, no human flight had ever gone beyond low Earth orbit. Going to the Moon meant flying suddenly *three hundred times* farther than any other crewed mission – the previous record belonged to Gemini 11, which had attained an altitude of 1,374 kilometers (854 miles) – and reaching a highly symbolic destination.



Figure 4.5-3. A Concorde *supersonic airliner flying at twice the speed of sound (approximately 2200 km/h or 1360 mph), photographed by military pilot Adrian Meredith in 1985.* Concorde *made its first flight in 1969.*

In other words, it should not be a surprise that the Moon missions were met with some disbelief. Considering that all subsequent human spaceflights, even Shuttle and Soyuz missions to the International Space Station or to service the Hubble Space Telescope, have never climbed more than 600 kilometers (372 miles) away from the Earth's surface, it's almost understandable that there is still some doubt about the Apollo flights, which reached a distance of *four hundred*

thousand kilometers (*nearly a quarter of a million miles*).

Such vast distances are hard to visualize. Consider that if you shrunk the Earth to a 40-centimeter (16-inch) ball, the Moon would be 10 centimeters (4 inches) in diameter and the Earth-Moon distance would be 11 meters (36 feet). At this scale, a flight to the International Space Station would rise above the Earth by *a single centimeter* (*less than half an inch*).

Disbelief is also partly justified because astonishment was, in a way, part of the intent of the Apollo program: president Kennedy's 1961 speech before a joint session of Congress made it very clear that *"No single space project in this period will be more impressive to mankind"*. Going to the Moon was unbelievable by design.

4.6 Origins and history of Moon hoax theories

Hoax claims regarding the Moon landings are not a recent phenomenon. In his book *A Man on the Moon*, Andrew Chaikin notes that they circulated even before the landings occurred, questioning Apollo 8's flight around the Moon in December 1968.[7]

There are anecdotal reports of doubters in the newspapers of the time, but it's difficult to find any hard figures. One year after the first Moon landing, an informal US poll by Knight Newspapers reported that over 30% of the 1,721 respondents were suspicious of NASA's claims.[8]

The figure rose to 54% among African Americans, although space historian Roger D. Launius notes that this *"perhaps said more about the disconnectedness of minority communities from the Apollo effort and the nation's overarching racism than anything else."*[9]

Many sources report that the very first pamphlet dedicated to the subject was *Did Man Land on the Moon?* by mathematician James J. Cranny, who self-published it in Johnson City, Texas, in 1970. Little is known, however, about its content or its author.

Moon hoax claims were soon referenced in popular culture. For example, in the movie *Diamonds are Forever* (1971), secret agent James Bond escapes by driving a stolen "Moon car" through a wall of an elaborate set where a moonwalk is being simulated rather ambiguously (Figure 4.6-1).



Figure 4.6-1. The "Moon set" in Diamonds are Forever *(1971). Credit: Metro-Goldwyn-Mayer Studios Inc.*

A rather bizarre Moon landing conspiracy theory reportedly circulated in Moscow in 1970: it claimed that the Soviet Lunokhod 1 rover, a remotely controlled vehicle which landed on the Moon in November of 1970, was actually *"driven by a midget KGB agent on a one-way suicide mission to the lunar surface"*, because Muscovites thought that Soviet technology was not up to the task of driving a robot on the Moon. Supporters of this theory, however, apparently had no trouble in believing that Soviet technology was capable of landing a human being on the Moon and somehow keeping him alive there for the eleven months during which Lunokhod 1 explored the lunar surface.[10]

7 *A Moon Landing? What Moon Landing?* by John Noble Wilford, *New York Times*, 18 December 1969, p. 30.

8 *The Wrong Stuff*, in *Wired* 2.09, September 1994; *Newsweek*, 20 July 1970; *Many Doubt Man's Landing on Moon*, *Atlanta Constitution*, 15 June 1970.

9 Roger D. Launius, *American Spaceflight History's Master Narrative and the Meaning of Memory*, in *Remembering the Space Age*, Steven J. Dick (ed.), 2008, p. 373-384.

10 Encyclopedia Astronautica, *KGB Dwarf*.

4.7 Bill Kaysing, grandfather of Moon hoax proponents

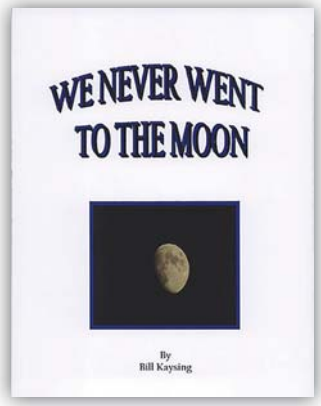


Figure 4.7-1. The cover of Bill Kaysing's book as currently available on Amazon.com.

The first widely publicized book promoting Moon hoax claims appeared in 1974, two years after the end of the Apollo lunar missions, when William Charles Kaysing (1922-2005) self-published the book *We Never Went to the Moon: America's Thirty Billion Dollar Swindle*, which presented a long list of alleged evidence that the lunar missions had been faked.

In *We Never Went to the Moon*, Kaysing presents a letter from the Rocketdyne Division of Rockwell International, which states that he was hired as senior technical writer in 1956 and subsequently worked there as service analyst, service engineer and publications analyst until he quit for personal reasons in May 1963. Rocketdyne built the Saturn V's rocket engines, so this would appear to qualify Kaysing as a significant authority on the Apollo project.

However, as his online biography acknowledges, Bill Kaysing had no formal technical education: he had a bachelor's degree in English literature. In his book he actually states that his *"knowledge of rockets and technical writing both equalled zero"* (page 30).

Moreover, Kaysing left Rocketdyne in 1963, well before the Moon missions began. It is therefore unlikely that his experience in the aerospace industry allowed him to acquire any special knowledge of the Apollo vehicles and technologies, which were still in the early stages of development when Kaysing quit and in any case were massively redesigned after the fatal fire of Apollo 1 in 1967.

Indeed, Kaysing makes the following remarks about the period after his employment at Rocketdyne:

> *I had not really given the Apollo program much thought in the years since leaving Rocketdyne. I had followed it in a cursory fashion, becoming aware of it only through the more startling developments: the fire on Pad 34, for example.*[...] *I watched none of the moon "landings" nor did I pay much attention to print media presentations.* [...] *I paid even less attention to the follow-on "flights" of Apollo and noticed that many others were equally neglectful."*
> *– We Never Went to the Moon*, page 7.

He also states that his disbelief was not based on the technical documents to which he had access, but on

> *"a hunch, an intuition; information from some little understood and mysterious channel of communication... a metaphysical message"* – *(ibid.)*.

In other words:

- Kaysing admittedly had no technical or scientific qualifications;
- he acknowledged that he knew nothing about spaceflight technology;
- he never worked at the technical departments of the Apollo project;
- and in any case left his job at Rocketdyne three years before the first test flight of an Apollo rocket.

As often happens with supporters of many kinds of conspiracy theory, their alleged authoritativeness vanishes when their credentials are cross-checked. Indeed, so far nobody having any significant qualification in the aerospace industry or at least in special effects technology has ever supported the "Moon hoax" theories.

4.8 *Capricorn One* and other "Moon hoax" movies

A major boost to the popularity of hoax theories came from the movie *Capricorn One*, directed by Peter Hyams in 1978, which presented an entertaining story of high-level rogues within NASA trying to save their face by faking a crewed Mars landing on a secret soundstage.



Figure 4.8-1. The poster for Capricorn One *(1978).*

The allusion to Moon hoax theories was rendered even more explicit by using Apollo hardware for the faked Mars landing. From a technical standpoint, this is utterly implausible, since the Martian atmosphere would require an aerodynamically shaped landing craft, not an angular Lunar Module designed for the airless Moon.

A further hint was the movie's tagline: *"Would you be shocked to find out that the greatest moment of our recent history may not have happened at all?"*.

Rather amusingly, conspiracy theorists hail *Capricorn One* as a prime example of how easily the Moon landings could have been staged despite the fact that the attempted fakery depicted in the movie actually *fails*: the fakers forget a crucial technical detail and their deception is spotted by a NASA engineer and disclosed spectacularly by a journalist. Moreover, the movie's technical explanation of the effects used to fake the landing is riddled with implausibilities and absurdities.

In later years, several movies have mentioned Moon hoax theories, often with a very tongue-in-cheek tone. Here is a sampling:

- In *Transformers: Dark of the Moon* (2011), the Apollo missions are real but the footage is faked to cover the actual reason for the Moon landings (recovering Transformer technology left on the Moon).
- In *Interstellar* (2014), future schools have rewritten history books to state that the Moon landings were faked by the US government to bankrupt the Soviet Union through an unsustainably expensive space race; this lie has been introduced to discourage people from trying to escape a dying Earth.
- In *Minions* (2015), the titular creatures wander in search of a new master to serve and stumble upon a movie set where a Moon landing is being simulated by a

director who looks like Stanley Kubrick.

- In *Moonwalkers* (2015), a CIA agent is tasked with recruiting Stanley Kubrick to produce fake footage of the first Moon landing just in case it can't be achieved, but ends up hiring an impostor who produces a pathetic fake.
- In *Operation Avalanche* (2016), two CIA agents discover that NASA can't actually go to the Moon and end up involved in a conspiracy to fake the Moon landing.



Figure 4.8-2. The Moon landing set in the movie Minions *(2015).*



Figure 4.9-1. The cover of Rene's book NASA Mooned America! *(1994 edition).*

4.9 Ralph Rene

Ralph Rene (1933-2008), a self-taught American writer and inventor with no formal background in spaceflight, self-published several editions of his book *NASA Mooned America!* in the early 1990s. The book rapidly became popular among conspiracists. His Moon landing fakery claims led to interviews for several television programs produced by The History Channel, National Geographic, Fox TV, Showtime and other networks around the world.

The 2001 Fox TV show *Did We Land on the Moon?* described him as a *"physicist"* and as an *"author/scientist"*, but Rene acknowledged in his own online biography that he *"did not finish college and is, therefore, without 'proper academic credentials.'"*

However, the same biography claims that he was a former *"consultant to NASA and the Rand Corporation"* with *"impeccable"* credentials because he had been contacted by Rand *"pleading for contributions of free inventions or thoughts relating to space for NASA", "at least one of his ideas"* had passed *"three sequential screening committees,"* and his name had been published in a NASA *"propaganda document"* regarding possible crewed missions to Mars. Here is his statement in full (Rene wrote in the second person):

> *... the Rand Corporation contacted him pleading for contributions of free inventions or thoughts relating to space for NASA. Two years later he received from the superintendent a free, full sized, thick, glossy page, full color NASA propaganda document. To his complete surprise he found his name printed in the middle of page A-51. To deserve this questionable honor, at least one of his ideas had to pass three sequential screening committees.*
>
> – ralphrene.com/biography.html (2008), archived at Archive.org

On his website and in his book *The Last Skeptic of Science* (1988), Ralph Rene argued that the official value of pi is wrong (the real one, he claimed was *exactly* 3.146264), that Einstein's theory of relativity is not valid and that Newton's law of universal gravitation is in error.

Despite Rene’s questionable background, his claims regarding the Apollo missions continue to this day to be quoted in traditional media and on the Internet. They will be discussed in detail in the chapters that follow.

4.10 Fox TV's *Conspiracy theory: Did We Land on the Moon?*



Figure 4.10-1. A still from the main title sequence of the Fox TV show.

In February and March 2001, the Fox TV network broadcast *Conspiracy theory: Did We Land on the Moon?*, a one-hour show which gave ample space to the allegations of hoax theorists (Ralph Rene, Bill Kaysing, Paul Lazarus, David Percy, Bart Sibrel and others) without any basic fact-checking and without providing any significant time for a technical rebuttal.

As a professionally-produced show broadcast on a national network, *Did We Land on the Moon?* appeared to be authoritative and consequently had a far greater impact on public opinion than the self-published efforts that had preceded it.

The show caused outrage in the aerospace community, yet was picked up and translated into several languages around the world, continuing to circulate despite the fact that each one of its claims has long been debunked by the astronomers and space professionals that Fox chose not to consult.[11]

11 A thorough debunking is available in *Conspiracy Theory: Did We Go to the Moon?*, by Prof. Steven Dutch, University of Wisconsin, and in *Fox TV and the Apollo Moon Hoax*, by Phil Plait, Ph.D., astronomer.

4.11 2002, the year Buzz made contact

The advent of the Internet as a popular medium in the early 1990s allowed all kinds of hoax theory proponents to spread their ideas rapidly. Low-cost camcorders and video editing systems gave them the means to produce many home-brew videos, disseminating them at first on videocassettes for sale and later directly on the Internet and on DVD.



Figure 4.11-1. Bart Sibrel in 2001.

This, together with the Fox show, led to an explosive production of Moon hoax videos and spawned a new generation of conspiracy theorists and theories. One of these theorists is Bart Sibrel.

In 2001, Sibrel released a 47-minute video, *A Funny Thing Happened on the Way to the Moon*, in which he claimed to have found a "secret" videotape of the Apollo 11 mission that proved the fakery.

The footage was actually a test TV transmission performed during the mission and was well-known to space experts and historians, but Sibrel's allegation and his appearance in the Fox TV show propelled him to great popularity in conspiracy theory circles.

Sibrel began following the Moon astronauts (even when they went to the supermarket) and asking them to swear on the Bible that they had really walked on the Moon. Some did; others refused.



Figure 4.11-2. Buzz Aldrin (right) initiates a hard docking maneuver with Bart Sibrel (far right).

On September 9, 2002, Sibrel chased Apollo 11 astronaut Buzz Aldrin with a cameraman and a sound technician in front of a Beverly Hills hotel and harassed him. Aldrin tried to avoid a confrontation, but in the end Sibrel accused the astronaut of being *"a coward and a liar"*. Aldrin, who was 72 at the time, replied with a punch to Sibrel's face. The first reaction of the 37-year-old hoax theorist was to ask his cameraman *"Did you get that on camera?"*

The incident attracted worldwide media attention and inevitably rekindled the Moon hoax debate. Charges against Aldrin were dropped when *"witnesses came forward to say that Mr Sibrel had aggressively poked Aldrin with the Bible before he was punched"*. Moreover, Sibrel *"sustained no visible injury and did not seek medical attention, and Mr Aldrin had no previous criminal record."*[12]



Figure 4.11-3. The confrontation between Sibrel and Aldrin [http://tiny.cc/lzyrbz].

12 *Ex-astronaut escapes assault charge*, BBC News, 21 September 2002.

Sibrel continued to pester Moon astronauts Alan Bean, Gene Cernan, Michael Collins, Al Worden, Bill Anders, John Young, Neil Armstrong and others, sometimes presenting fake credentials (for example to Edgar Mitchell, who threw him out of his home).



Figure 4.11-4. Bart Sibrel in a picture published in 2015 by the Daily Star*.*

According to Clavius.org, he trespassed on Neil Armstrong's property while trying to confront him with his hoax allegations (Armstrong called the police). Sibrel was subsequently fired from his job as a cameraman for a Nashville TV station.

Another Sibrel video, *Astronauts Gone Wild* (2004), showed Cernan, Bean and Mitchell swearing on Sibrel's Bible that they did go to the Moon, as the conspiracy theorist demanded. Despite this, Sibrel still claims that the Apollo Moon landings were faked. The video also showed Armstrong politely refusing and saying *"Mr Sibrel, knowing you, that's probably a fake Bible."*

Sibrel stated in 2015 that he intended to quit his efforts: *"I am going to put it all behind me. I've not enjoyed this process in the slightest. I got kicked out of church, I got unfriended by many people because of what I believe, that the Moon landings are fake. It's been an interesting experience but so be it."*[13]

13 *Filmmaker has 'proof the Moon landings were a CIA HOAX', Daily Star*, 8 November 2015, reissued on 21 July 2018.

4.12 Other notable hoax proponents

Moon hoax theorists and their claims have achieved significant popularity in many other countries besides the United States.

British film and TV producer David Percy co-authored a book, *Dark Moon: Apollo and the Whistle-Blowers* (2001), and produced a video, *What Happened on the Moon?* (2000), alleging varying degrees of fakery.

French writer Philippe Lheureux argued in his book *Lumières sur la Lune* (*"Lights on the Moon"*, 2002) that Americans went to the Moon but published fake photographs to prevent other countries from making use of the scientific information gathered by the flights.

German author Gernot Geise published three books, *Der Mond ist ganz anders* (*"The Moon is completely different"*, 1985, republished in 2003), *Die dunkle Seite von Apollo* (*"The dark side of Apollo"*, 2002, republished in 2006), and *Die Schatten von Apollo* (*"The shadow of Apollo"*, 2003), arguing not only that the Moon landings were faked, but that key facts about the Moon itself, such as its true gravity and the presence of vegetation and ancient buildings, have been kept secret by NASA.

Gerhard Wisnewski and Willy Brunner promoted Geise's allegations on German TV in their documentary *Die Akte Apollo* (*"The Apollo File"*, 2002). Wisnewski also published the book *Lügen im Weltraum* (*"Lies In Space"*, 2005) covering the same themes.

Roberto Giacobbo, anchor and assistant director of Italy's national TV network RAI, brought Moon hoax theories to large television audiences with his *Voyager* series in 2009.



Figure 4.12-1. Italian TV anchor Roberto Giacobbo talks about Moon hoax theories in an episode of Voyager *(2009), The upper caption says* "Moon, another story?"*.*

Italian politician and member of Parliament Carlo Sibilia, of the Five Star Movement, in 2014 stated on Twitter that *"nobody has the courage to say that [the Moon landing] was a farce"*. In 2018, while acting as undersecretary for the Ministry of the Interior (or Home Office) of the Italian government, Sibilia confirmed his claims in an interview to the newspaper *Corriere della Sera*, stating that the Moon landing was *"a controversial episode"*.

Several US celebrities have endorsed Moon hoax theories. Actress Whoopi Goldberg did so on the TV show *The View* (2009). Basketball player Carl Everett (2000), TV presenter and comedian Joe Rogan (2010), rapper Mos

Def (2008) and writer Margaret Atwood have at the very least publicly questioned the authenticity of the Moon landings.[14]

14 *Margaret Atwood's 'just wondering' about that silly moon landing hoax*, *National Post*, 23/9/2010.

Several Russian authors, such as journalist and politician Yuri Mukhin and science professionals such as Alexander Popov and Stanislav Pokrovsky, have also voiced their claims of conspiracies in articles, books and websites.

4.13 The four fundamental hoax scenarios

There are many Moon hoax claims, leading to multiple alternative explanations of what allegedly actually happened. As is often the case in the bizarre world of conspiracy theories regarding many events, for the Moon landings there is a single "official" version, which is self-consistent, extensively documented and widely accepted by the experts, and there are many alternative versions of the hoax scenario, which contradict each other.

Accordingly, it can be highly instructive, and sometimes entertaining, to avoid the usual debate between "believers" and "skeptics" and instead arrange a confrontation among Moon hoax proponents that support different and mutually incompatible versions of the way the events were faked.

Knowing these various aspects of Moon hoax theories is important, because it highlights their inconsistencies and shows that many conspiracy theorists and doubters haven't really thought through the consequences and implications of their pet arguments and therefore end up making self-contradictory statements, as detailed in the chapters that follow.

We never went. Ever

Supporters of this theory allege that NASA lacked the technology for a Moon landing and that even today the radiation of the Van Allen belts that surround the Earth is a lethal barrier to any crew venturing away from our planet.

Accordingly, they argue that all crewed flights to the Moon, including Apollo 8, 10 and 13, which orbited around the Moon without landing, had to be faked.

Therefore, they claim, all the photographs and film footage, the radio and TV broadcasts and the telemetry from the lunar surface and from lunar orbit had to be faked by using special effects. Likewise, the lunar rocks and all the science brought back from the Moon had to be fabricated or acquired through other means.

This scenario implies the need to fake every detail of *nine* complete lunar missions: six Moon landings and three flights around the Moon.

Supporters of this theory allege that NASA failed in this immensely



Figure 4.13-1. Artist's impression of Moon fakery movie set. Credit: Moise.

complicated simulation of so many missions and that the skeptical eye of hoax theorists was sharper than the experts' vision in spotting mistakes and anomalies in the pictures and in noting scientific impossibilities.

We went, but the first landing was faked

Some conspiracy theorists argue that only the first Moon landing (Apollo 11) was faked because the vehicles were not ready or were untested, but all the previous and subsequent missions were real.

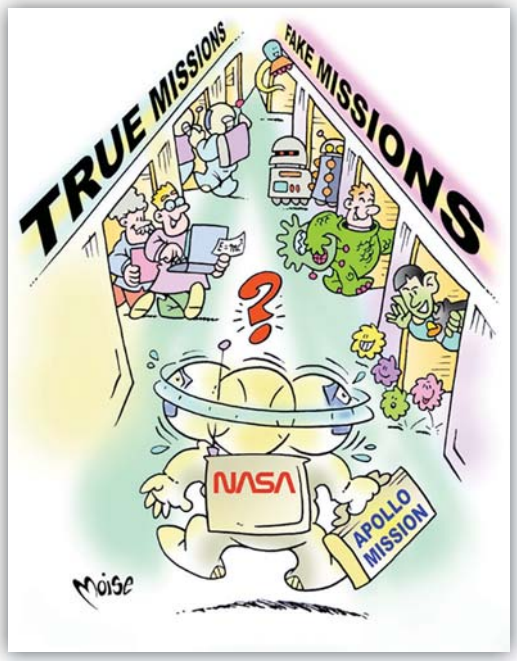


Figure 4.13-2. Artist's impression of true/fake mission sorting process. Credit: Moise.

This theory seeks to explain, for example, the difference in quality between the grainy, black-and-white television footage of the first landing and the sharper color images of the subsequent Moon missions.

It also appears to justify the difference in quality and quantity between the photographs taken by Apollo 11 and those taken by all the later missions, as well as the use of different spacesuits and the far longer duration of the moonwalks: the Apollo 11 astronauts made a single lunar excursion that lasted two and a half hours, yet Apollo 12 already had two moonwalks that lasted almost four hours each.

The fact that the Apollo 11 moonwalkers stayed very close to their landing spot, differently from all the other missions, is explained by the need to stay within the confines of the movie set.

The initial fakery, in other words, was meant to fool the Soviet Union into believing that it had lost the race to the Moon and gain time to go there for real later.

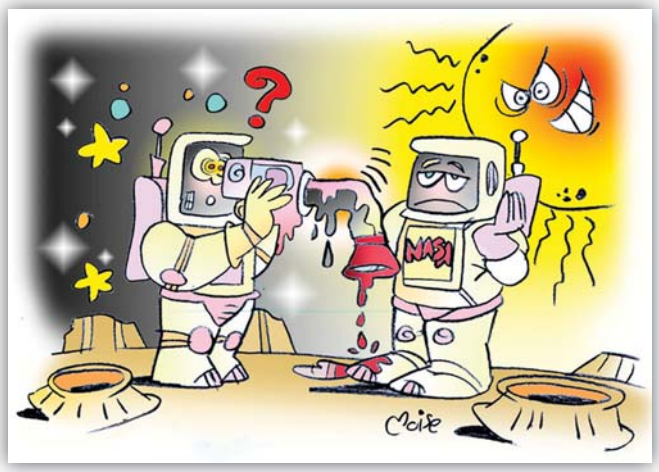


Figure 4.13-3. Artist's impression of film liquefaction issues. Credit: Moise.

We went, but the photos were faked

Another school of thought claims that the Moon missions were all real but their photos were unusable and had to be faked. The films, it is argued, were fogged by cosmic radiation, melted by the excessive heat in the sun, or frozen by the extreme cold of lunar shadows, or the lighting on the Moon was so unearthly that the camera settings were wrong and the resulting photographs were unacceptable in terms of propaganda effectiveness.

A variation on this theory suggests that the real photos contained scientific information that the US did not want to share with rival countries and therefore a set of simulated pictures was prepared.

We went, but we found ET

The fourth main scenario of Moon hoax theories argues that perhaps not all the landings were real, but we did go to the Moon sooner or later, only to find that it was already occupied by extraterrestrials.



Figure 4.13-4. Artist's impression of unexpected discoveries on the Moon. Credit: Moise.

Proponents of this theory say that some photos show UFOs in the lunar sky and that clandestine recordings document the astonishment of the astronauts as they discovered that they were not alone on the Moon.

Some claim that mankind has not returned to the Moon since those first landings because the aliens have told us to stay away. Others say that additional secret Moon missions were carried out to recover abandoned alien vehicles, from which NASA extracted the technologies for the Space Shuttle and for many other covert military projects.

That's really what they say

Before you ask: no, these four main scenarios are not fabrications of the supporters of the "official" story, designed to ridicule Moon hoax proponents. Each one of these scenarios is documented in the books, videos and Internet sites of the various conspiracy theorists. There are even more ludicrous ones.

More importantly, the supporters of each one of these four main theories claim that they have incontrovertible evidence of their allegations, which contradict the other competing conspiracy scenarios. Standing aside and watching these people argue among themselves, therefore, can be extremely enlightening.

None of these people, however, has any experience or skill in the aerospace industry and there are no doubters or hoax proponents among today's astronauts and employees of the various national space agencies, such as Russia's Roscosmos, Europe's ESA, India's ISRO or Japan's JAXA.

4.14 None of the experts have doubts

Supporters of Moon hoax theories claim to have found many anomalies in the photographs and footage of the Apollo missions and to have identified several technical and physical impossibilities that prove their hoax claims.

In actual fact, these alleged anomalies and impossibilities exist only in the opinion of people who are not experts in the relevant fields. Anyone who is professionally involved in photography, space technology or astronomy knows very well that what a layman might consider strange or implausible is instead exactly what science expects to occur in the unfamiliar environment of space and on the Moon.

Only incompetent amateurs question the authenticity of the Moon missions. In all the decades that have passed since the Apollo program, no real expert has ever raised documented doubts.

On the contrary, many of the apparent anomalies actually *authenticate* the visual record of the Apollo missions, as explained by Dennis Muren, winner of six Academy Awards for the visual effects of movies such as *Jurassic Park*, *Terminator 2*, *The Abyss*, *E.T.* and *Star Wars*:

> *"A moon landing simulation* [produced with the special effects of the 1960s] *might have looked pretty real to 99.9 percent of the people. The thing is, though, that it wouldn't have looked the way it did. I've always been acutely aware of what's fake and what's real, and the moon landings were definitely real. Look at* 2001 *or* Destination Moon *or* Capricorn One *or any other space movie: everybody was wrong. That wasn't the way the moon looked at all. There was an unusual sheen to the images from the moon, in the way that the light reflected in the camera, that is literally out of this world. Nobody could have faked that."*
>
> – *The Wrong Stuff*, by Roger van Bakel, *Wired* (1993).

The second part of this book will sort the alleged hoax evidence into categories and debunk each claim systematically by using technical facts.

You probably won't be surprised that the house of cards of the lunar conspiracists' "evidence" ultimately collapses completely; but it's very insightful to explore the nature of the recurring errors and patterns of thought on which these theories are based.

Moreover, disproving some of this evidence requires considerable research, especially because hoax theorists usually present documents, photographs and videos without specifying their source or the mission to which they relate, and also requires familiarity with the errors and deceptions often made by hoax theory proponents. This makes it hard even for many experts in astronomy or aerospace technology to find the exact technical explanation of some alleged anomalies and to provide accurate answers to the Moon hoax questions that often come up during their public talks.

One of the purposes of this book is to gather the explanations that have already been provided over the years and offer a handy guide to answering these questions.

5 Alleged photographic anomalies

Many Moon hoax proponents claim that there is evidence of blatant fakery in the photographs that NASA presented to the world over half a century ago. Most of these claims, however, are based on a lack of understanding of the basic principles of photography.

This is not really surprising, especially today, when many people have never used anything other than the fully automatic digital camera embedded in their mobile phone and therefore are unfamiliar with the technical issues of photography in general and know even less about the use, capabilities and limitations of chemical photography of the Sixties.

Today the concepts of not seeing a picture as soon as it is taken, of setting exposure and focus manually, of film sensitivity levels, and of dipping a strip of flexible film into chemicals in darkness to reveal a picture sound rather quaint and arcane, like a gramophone in the iPod era. Yet that's how countless masterpieces of photography were taken for over a century and a half, and that's how photographs were taken on the Moon trips.

Many of today's young adults have never handled an actual professional camera (digital or otherwise) and often have no idea of what photographic film was. So I apologize in advance if some of the technical explanations seem rather dumbed down and pedantic.

5.1 Apollo still photography: a quick primer

Approximately 20,000 still pictures were taken during the Apollo missions, all using *photographic film*: thin strips of transparent material, coated with special chemicals that react when exposed to light and reveal a color or black-and-white image when they are immersed in special baths of other chemicals. There were no digital cameras at the time.

The cameras taken to the Moon by the Apollo astronauts used mostly Kodak Ektachrome MS and EF color film, with a *speed* (sensitivity to light) of ISO 64 and 160 respectively, and Kodak Panatomic-X black-and-white film, with a speed of ISO 80 (ASA units were used in the 1960s instead of ISO, but they are fully equivalent).

Both films were in the 70 mm format, which means that the film strip was 70 millimeters (2.75 inches) wide. The *resolution* (capacity to record fine details) of these films was impressive even by today's standards: 80 lines per millimeter for color film and 170 lines per millimeter for black-and-white. In today's digital units, that's roughly equivalent to 40 megapixels for color pictures and to a whopping 160 megapixels for black-and-white ones, according to the Arizona State University's state-of-the-art Apollo image scanning project.



Figure 5.1-1. A portion of 70 mm photographic film similar to the one used for the Apollo flights. The film shown is a duplicate of an original Apollo 16 film. The white flecks are fragments that broke off the spacecraft during the extraction of the Lunar Module. Source: Terapeak.com.

So-called *color reversal* film was used for the color photos. This kind of film produces *slides* (transparencies) that can be viewed directly instead of *negatives* (images with reversed colors) that need to be printed. This choice might appear unusual, since negative film is more tolerant to difficult lighting and to over- and underexposures, but it was dictated by the awareness that negatives would have entailed color accuracy problems: photographs taken in space or on the Moon often don't include any familiar objects that can be used as a color reference and therefore print lab technicians would not have known how to set their printing equipment correctly to render the true colors. Color reversal film doesn't have this problem.

The Apollo films were derived from the ones used for high-altitude photo reconnaissance, which were designed to withstand temperatures down to -40°C (-40°F). Their special Estar polyester base had a melting point of 254°C (490°F) and was thinner than usual, allowing to store enough color film for 160 photographs or black-and-white film for 200 photos in a *magazine*: a removable and light-tight container.

These magazines constituted the rear portion of the custom-built, motorized Hasselblad 500EL cameras used for nearly all the photographs taken during the lunar excursions. These cameras had manual exposure and focus setting and a lens with a fixed focal length (i.e., no zoom). On the lunar surface, Apollo missions 11 to 14 only had a single Zeiss Biogon wide-angle (60 mm) lens; later missions added a 500 mm telephoto lens.

Film advancement was controlled automatically by the electric motor of the camera (the lower block in Figure 5.1-3).

Inserting the film in the magazine wasn't trivial, as shown in the video in Figure 5.1-4, which relates to a camera that is very similar to the ones used on the Moon but shows a much shorter film roll than the Apollo roll shown in Figure 5.1-5.

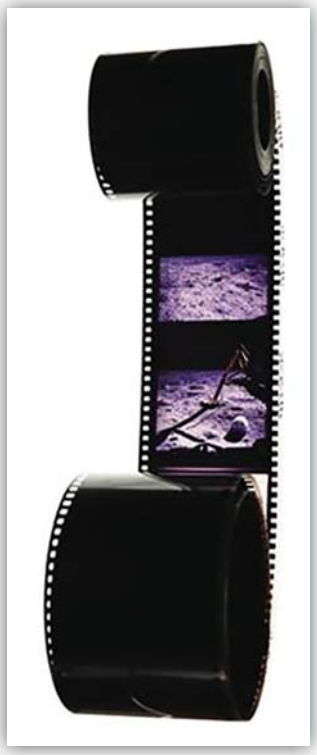


Figure 5.1-2. A contact duplicate of the 70 mm film used on the Moon for the Apollo 11 mission, from Buzz Aldrin's personal collection. It was auctioned in 2008 for approximately 6,000 dollars. Source: Icollector.com.

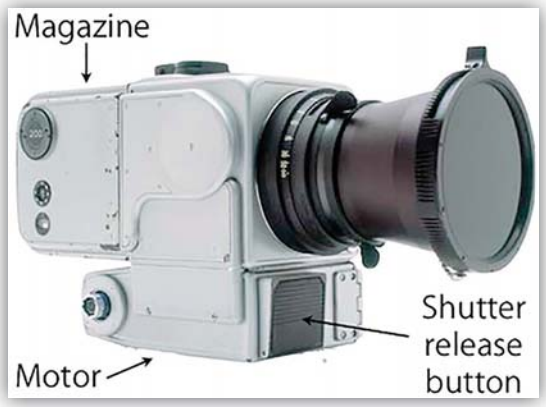


Figure 5.1-3. A Hasselblad 500EL lunar excursion camera. Credit: Hasselblad.com.

Accordingly, this procedure was performed by technicians on the ground long before liftoff.

The cameras had large adjustment levers to allow handling even with the thick gloves of a lunar spacesuit. The shutter release button was much larger than normal for the same reason.

Focusing was guided by distance markings on the lens and simplified by the considerable *depth of field* (range of distances over which objects are in focus) of the wide-angle lens at the settings allowed by the bright sunlight: the recommended *aperture* (also known as *f-stop*) was f/5.6 for photographs in shadow and f/11 for taking pictures of subjects in full sunlight. The standard exposure time was 1/250th of a second. The film magazines carried a sticker which reminded the astronauts of these settings, which had to be made manually.





Figure 5.1-4. Inserting film in a Hasselblad magazine [http://tiny.cc/pwrzbz].

The Hasselblad cameras had no viewfinder, since the astronauts would have been unable to use one while wearing their helmets, and there was no on-screen preview like we have today with digital cameras and mobile phones, so aiming was done by pointing the camera roughly in the direction of the subject. The moonwalkers were aided in this by their extensive photography training and by the wide field of the lens (approximately 49° width and height, 66° diagonal).



Figure 5.1-5. A Hasselblad technician prepares a film magazine for Apollo missions. The mechanism for supporting the film on two spools can be seen in the foreground. Photo C-81-4. Source: ALSJ/ Ulli Lotzmann.

A silver-colored coating was applied to the camera bodies used on the lunar surface, in order to reflect the light and heat of the sun and reduce the risk of overheating. Onboard cameras were coated with a more traditional black.

For Apollo 15, 16 and 17, special automatic cameras were installed in a fixed position on board the Service Module. These cameras were used to map the Moon and were called *Metric Camera* and *Panoramic Camera*; they took photographs of the lunar surface from orbit and recorded them on film that was 12.7 centimeters (5 inches) wide. To provide a geographical reference, these cameras were coordinated with a *Stellar Camera*, which used 35 mm film to take pictures for the stars located at the *zenith* (directly overhead) of the region being overflown.



Figure 5.1-6. A film magazine used for the Apollo 11 mission. Note the sticker that reminded the astronauts of the settings for the various lighting conditions.

Apollo 11, 12 and 14 also used film to take close-up *stereo pair* photographs of the lunar soil. This was done with the *Apollo Lunar Surface Closeup Camera* (*ALSCC,* Figure 5.1-7), which was meant to be placed on the ground. The film was about 25 centimeters (10 inches) from the ground and was exposed in fixed conditions (1/100th of a second, f/22.6) thanks to a built-in electronic flash. Each photograph generated two images taken from slightly different angles and covered a ground area of approximately 75 by 75 millimeters (3 inches).

The astronauts of Apollo 16 and 17 also used a Nikon camera with 35 mm film to take photographs inside the spacecraft and through the windows to record the visible stars.

All these films are stored at the Film Archive in Building 8 at the Johnson Space Center (JSC) in Houston, in a freezer at -18°C (-0.4 °F) located inside a cold storage room kept at 13°C (55 °F).

Having established this basic information on the techniques used for the still pictures taken on and around the Moon by the Apollo astronauts, we can now deal with the alleged anomalies that hoax supporters claim to have found in these images.

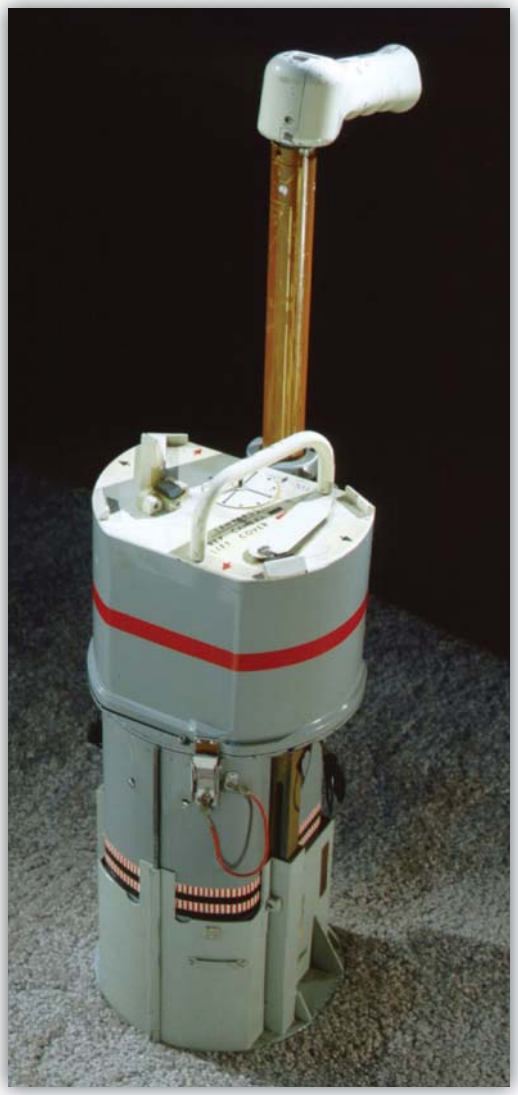


Figure 5.1-7. The ALSCC (Apollo Lunar Surface Closeup Camera). Credit: Planetary Society/National Air and Space Museum, Smithsonian Institution.

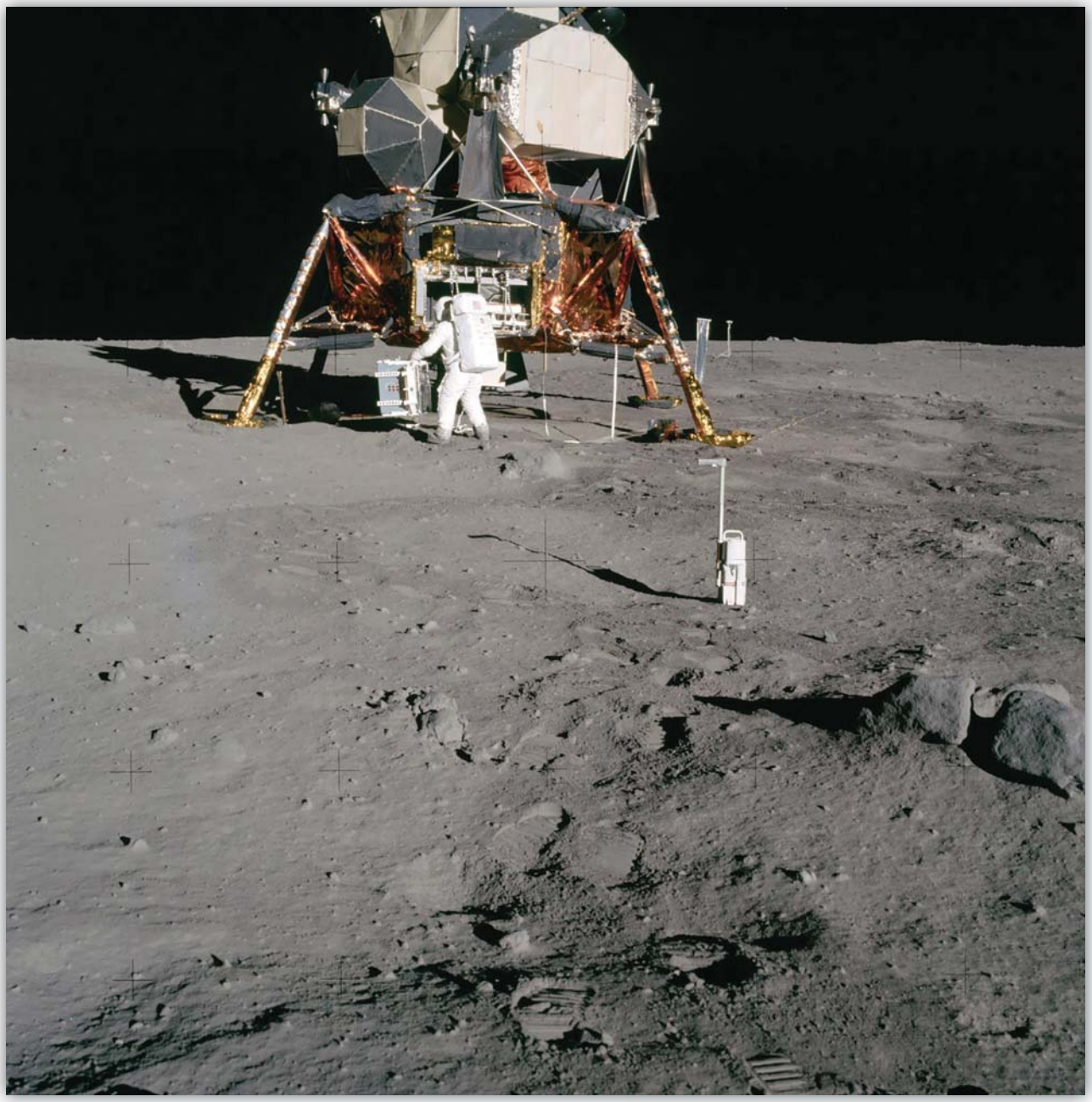


Figure 5.1-8. Center right: the ALSCC on the Moon during Apollo 11. The astronaut in the photograph is Buzz Aldrin. NASA photo AS11-40-5931.



Figure 5.1-9. The inside of the cold storage room that preserves the original Apollo films. Left: the freezer; right, films being thawed slowly to scan them. Credit: Apollo Image Archive.



Figure 5.1-10. Containers of original films of the Apollo missions inside the cold storage rooms. Labeling in the foreground refers to Skylab and Apollo-Soyuz flights. Credit: Apollo Image Archive.



Figure 5.1-11. Containers of original Apollo films from the Apollo 15 reconnaissance camera. Credit: Apollo Image Archive.

5.2 Why are there no stars in the photographs?

IN A NUTSHELL: *Because there shouldn't be any. The surface of the Moon at the landing site was in daylight, so the cameras were set for daylight. Stars are too faint to be photographed with daylight settings. The same thing also happens in Russian and Chinese photos taken on the Moon and in space with these settings. Only Venus shines brightly enough to be photographed, but it's a planet, not a star, and it's far brighter than actual stars.*

THE DETAILS: This is usually the very first objection raised by doubters: why aren't there any stars in the Apollo



Figure 5.2-1. Ed White during his spacewalk (Gemini 4, 1965). No stars. NASA photo GPN-2006-000025.

photographs? After all, illustrations and movies that depict the Moon often show the stars in the sky.

However, this is an artistic license. Adding stars makes a picture much more interesting, but it's scientifically inaccurate. In actual fact, the sky is starless in *all* photographs ever taken in space in sunlight with normal daylight settings.

There are no stars in pre-Apollo pictures, such as the one shown in Figure 5.2-1, which was taken in 1965 in Earth orbit during the Gemini 4 mission.

There are also no stars in more recent daylight space photographs, such as the ones taken by the astronauts of many countries who flew on the US Space Shuttle or on the Russian Soyuz spacecraft (Figure 5.2-2).

There are no stars in the daylight photos taken from the International Space Station (Figure 5.2-3).

No stars can be seen also in the photographs taken on the Moon by the Chinese Chang'e 3 uncrewed spacecraft, which

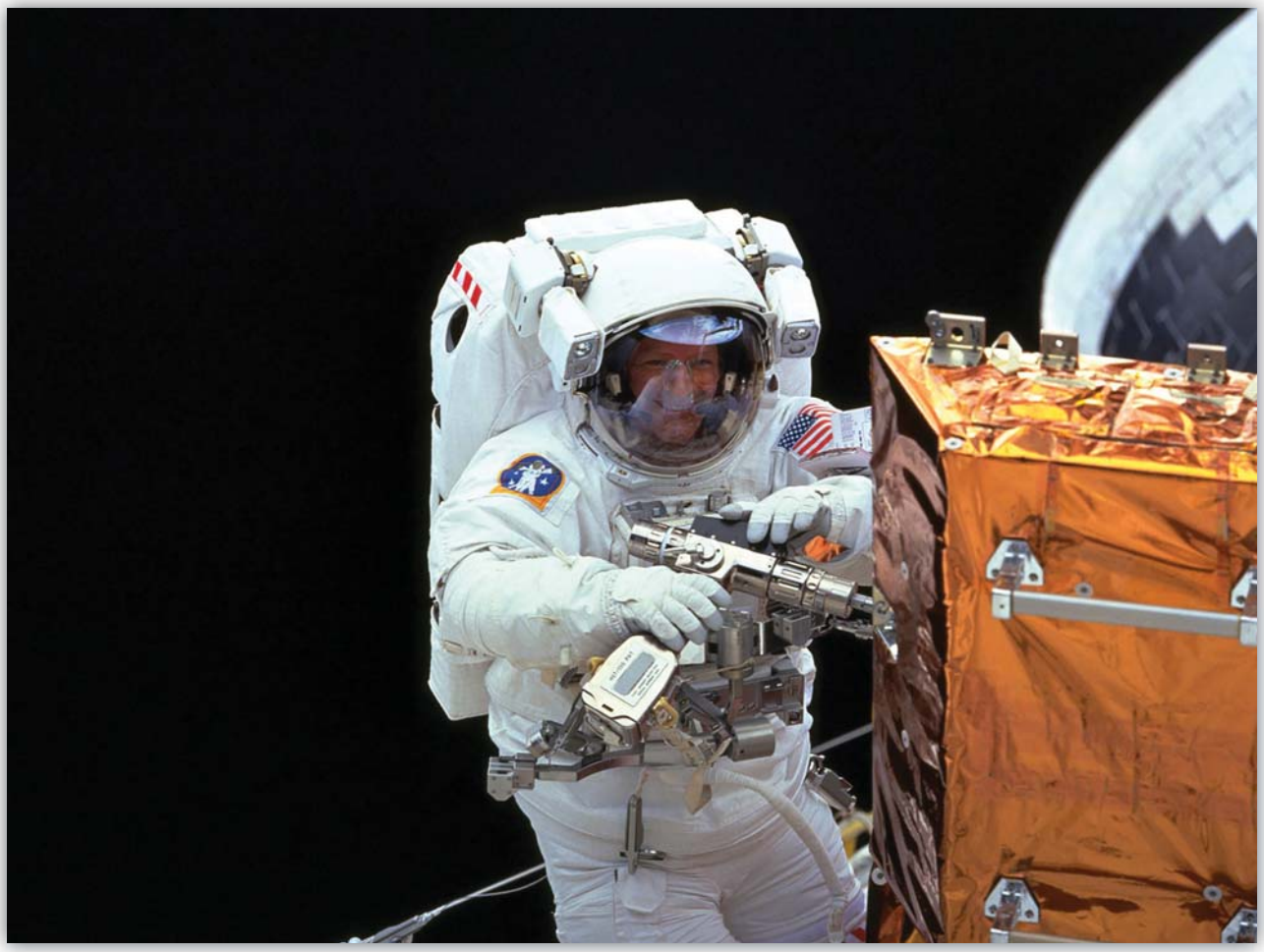
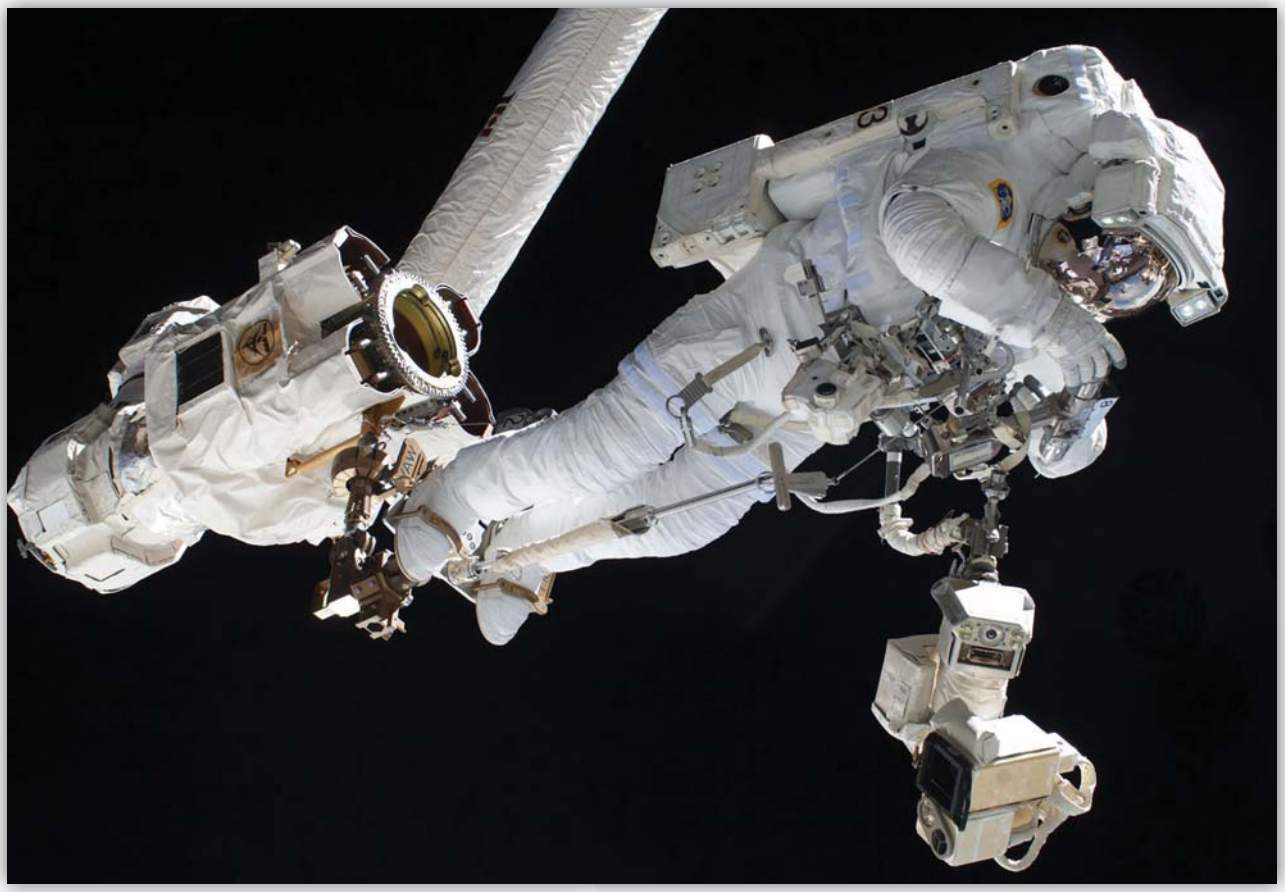


Figure 5.2-2. Swiss astronaut Claude Nicollier against the blackness of space during Shuttle mission STS-103 (1999). No stars.



Above: Figure 5.2-3. Italian astronaut Luca Parmitano outside the International Space Station in 2013. No stars. Source: DLR. Credit: ESA/NASA.



Figure 5.2-4. The sky of the Moon, photographed by the Chinese Chang'e 3 spacecraft (2013). No stars. Source: Sina.com.cn.



Figure 5.2-5. Chang'e 3, photographed on the Moon by the digital camera of the Yutu rover. No stars. Source: Sina.com.cn (2013).

landed in Mare Imbrium on 14 December 2013, performing the first soft landing on the Moon in 37 years (the previous one dated back to 1976, with the Soviet Luna 24 uncrewed spacecraft).

Stars are not visible in the pictures transmitted from the lunar surface by Soviet probes Luna 9 (1966), Luna 13 (1966), Luna 17 (1970) and Luna 21 (1973). These images are available at the *Soviet Lunar Photos* website.

These international examples make it clear that the lack of stars in photographs taken in space and on the Moon is absolutely normal.

The reason is very simple: stars are far too faint to be recorded by a camera set for daylight photography like the Moon cameras were. You can test this easily: take a photograph in daylight with a camera that allows manual settings and make a note of

the exposure time and *aperture* (the number after the *"f/"*) that yield a good picture. Then try taking a photograph of a clear night sky with the same settings. The sky will turn out pitch black, except for the Moon and possibly Venus.



Figure 5.2-6. The lunar sky photographed by the Chang'e 3 probe. In the foreground, the Yutu rover. No stars. Source: Sina.com.cn (2013).

The astronauts couldn't see any stars while they were on the Moon for the same reason. If you stand in a city street at night, your eyes are dazzled by car headlights and street lighting, so you'll have trouble seeing any stars. Imagine how dazzled the moonwalkers were by the *entire lunar surface* all around them bathed in direct sunlight. If you've noticed how bright a full Moon is and how it blocks out the stars in the night sky, just think how bright it must be when you're actually *standing* on that Moon.

This is a basic concept of photography and optics, so those who question the lack of stars in the Apollo visual record are simply revealing their lack of technical knowledge. That's what prominent Moon hoax theorist Bill Kaysing did



Figure 5.2-7. Italy by night, seen from the International Space Station. One of the Station's robot arms is at the center and is gripping a Cygnus cargo vehicle. The stars can be seen because the camera is set for night photography. The dots of light in the sea are ships. Source: NASA, 2014.

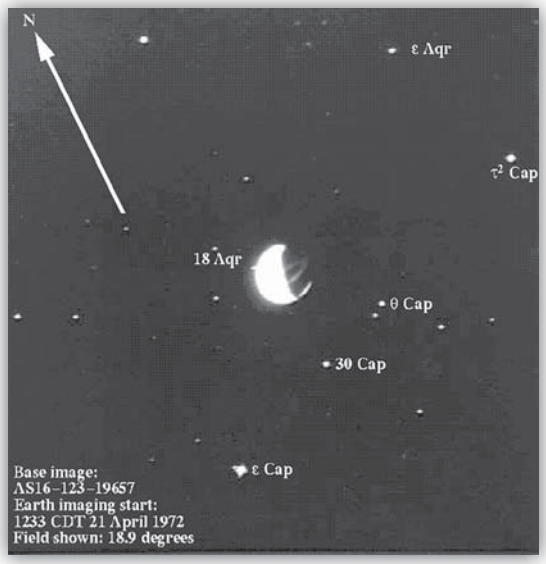


Figure 5.2-8. A sample of ultraviolet star photography from Apollo 16 (photo AS16-123-19657).

when he asked *"Where are the stars in the lunar sky?"* in his book *We Never Went to the Moon* (page 23).

Faint starlight can be photographed by adjusting cameras to night settings. This is what astronauts do today to take pictures of the stars from the International Space Station with their highly sensitive digital cameras when the Station flies over the night side of the Earth.

Beautiful pictures such as the one shown in Figure 5.2-7 can be taken only by choosing a long exposure time (1/6th of a second), the greatest possible aperture (f/1.4) and a very high sensitivity (12800 ISO). The photographs taken by the astronauts on the Moon, instead, were set to 1/250th of a second, an aperture of f/5.6 or f/11 and a sensitivity between 64 and 160 ISO.

However, it is incorrect to say that there are no stars *at all* in any of the pictures taken on the Moon during the Apollo missions. For example, photograph AS16-123-19657 (Figure 5.2-8) shows the stars of Capricorn and Aquarius as a backdrop to the Earth. However, it wasn't taken on

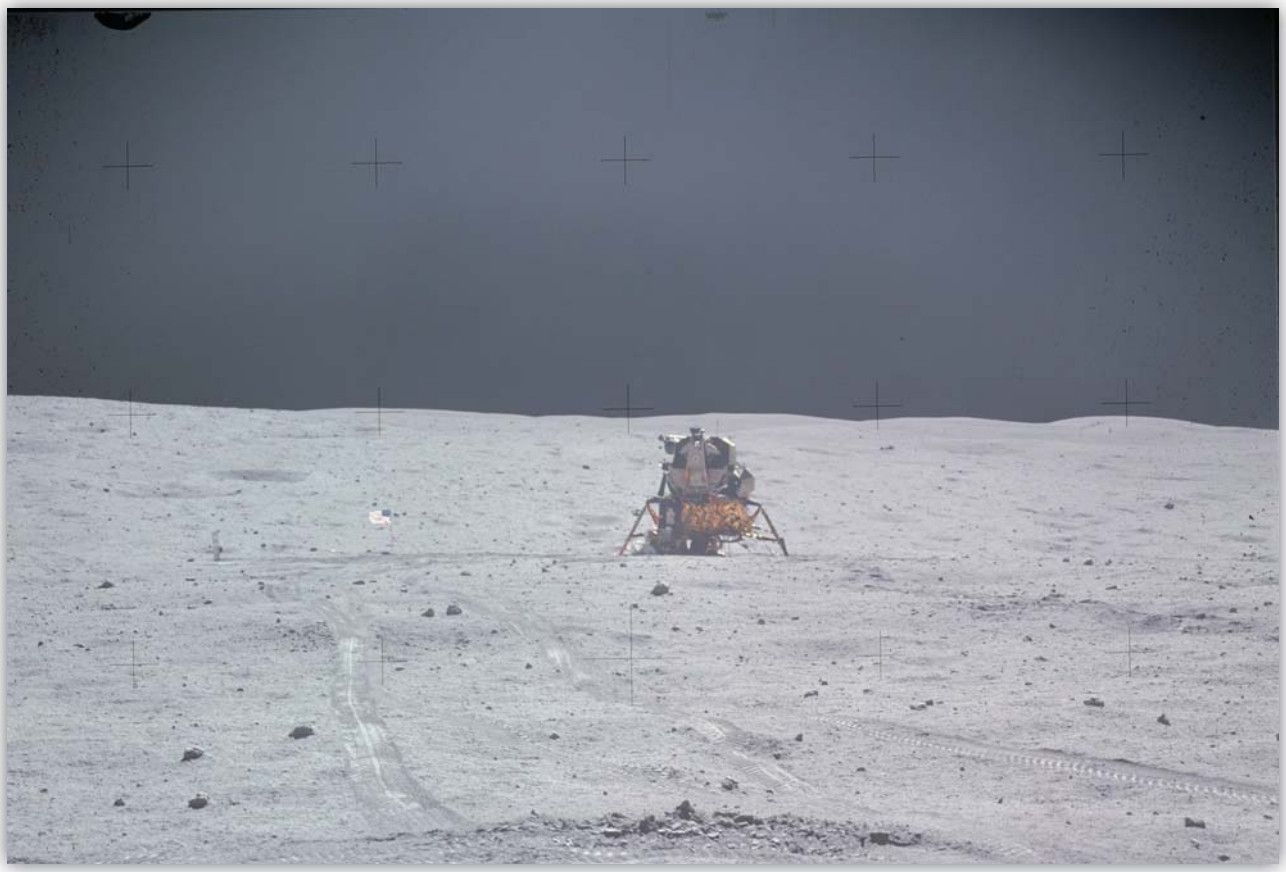


Figure 5.2-9. Venus is in the picture, but where? Photo AS16-117-18815 (cropped).



Figure 5.2-10. Photo AS16-117-18816 (cropped).

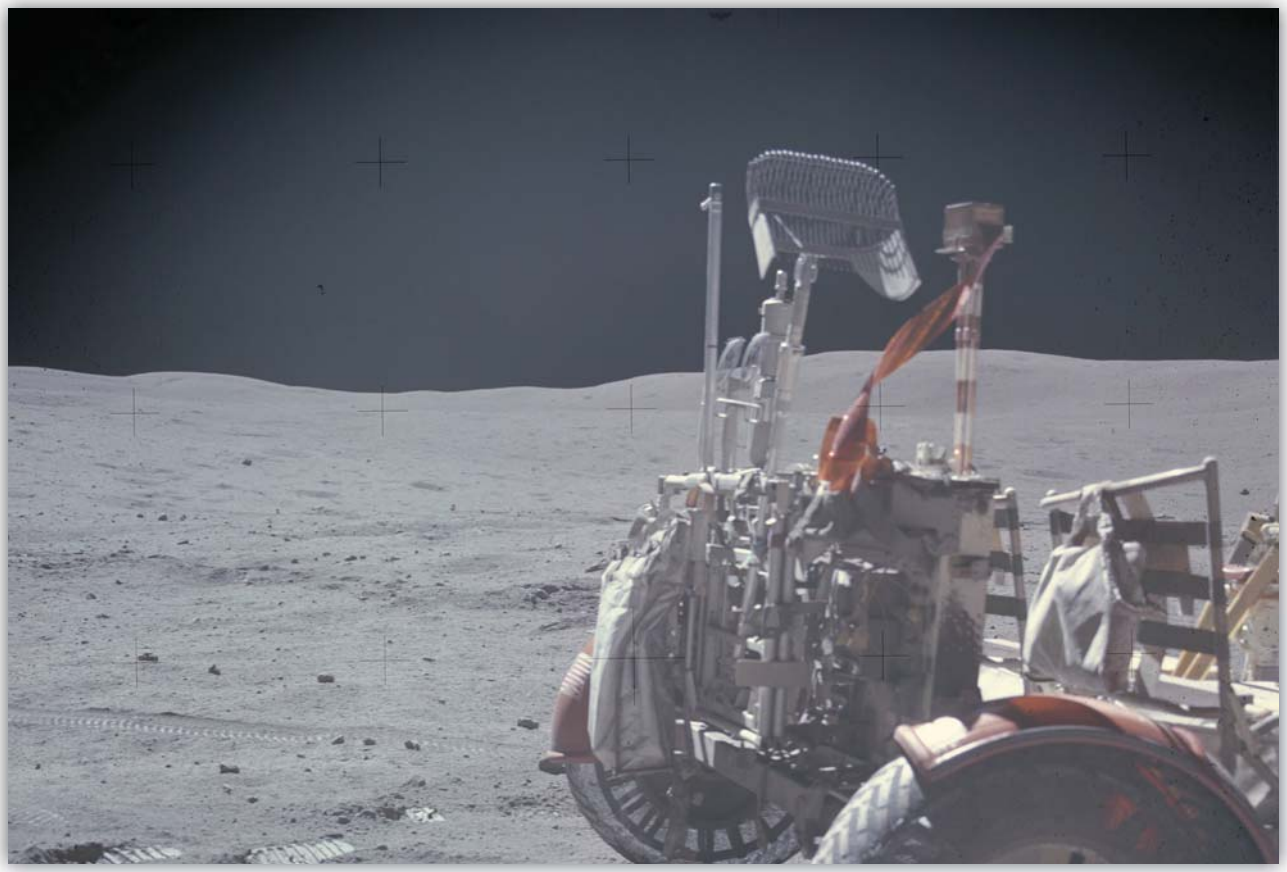


Figure 5.2-11. Photo AS16-117-18817 (cropped).

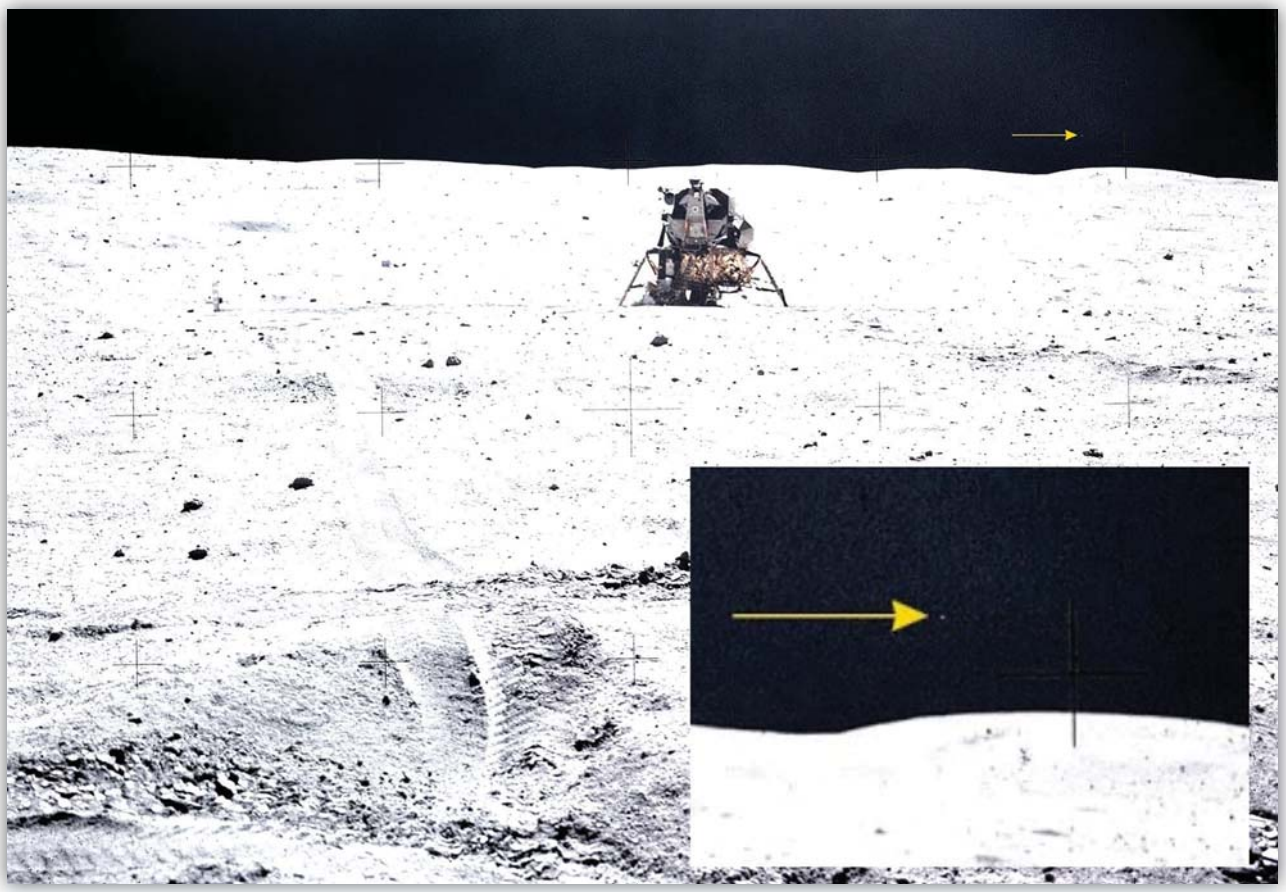


Figure 5.2-12. Photo AS16-117-18815 (processed and annotated).

the Moon with an ordinary camera, but with a telescope loaded with ultraviolet-sensitive film, using night settings (a long exposure time), during the Apollo 16 mission in April 1972, taking care not to include the extremely bright lunar surroundings.

The Apollo visual record also includes pictures of other heavenly bodies, although strictly speaking they're not stars. For example, NASA photos AS16-117-18815, -18816 and -18817 (Apollo 16), taken with daylight settings, faintly show Venus, which is a planet, not a star, and is far brighter than any actual star, so much that you can see it in broad daylight on Earth if you know where to look.

Can you spot Venus in the photographs in Figures 5.2-9 to 5.9-11? You may have to click them in order to enlarge them. Venus is just above the rightmost hill in Figure 5.2-9.

Perhaps it's easier to locate Venus in the version of Figure 5.2-9 shown in Figure 5.2-12, in which contrast has been boosted and an arrow and an enlarged detail have been added.

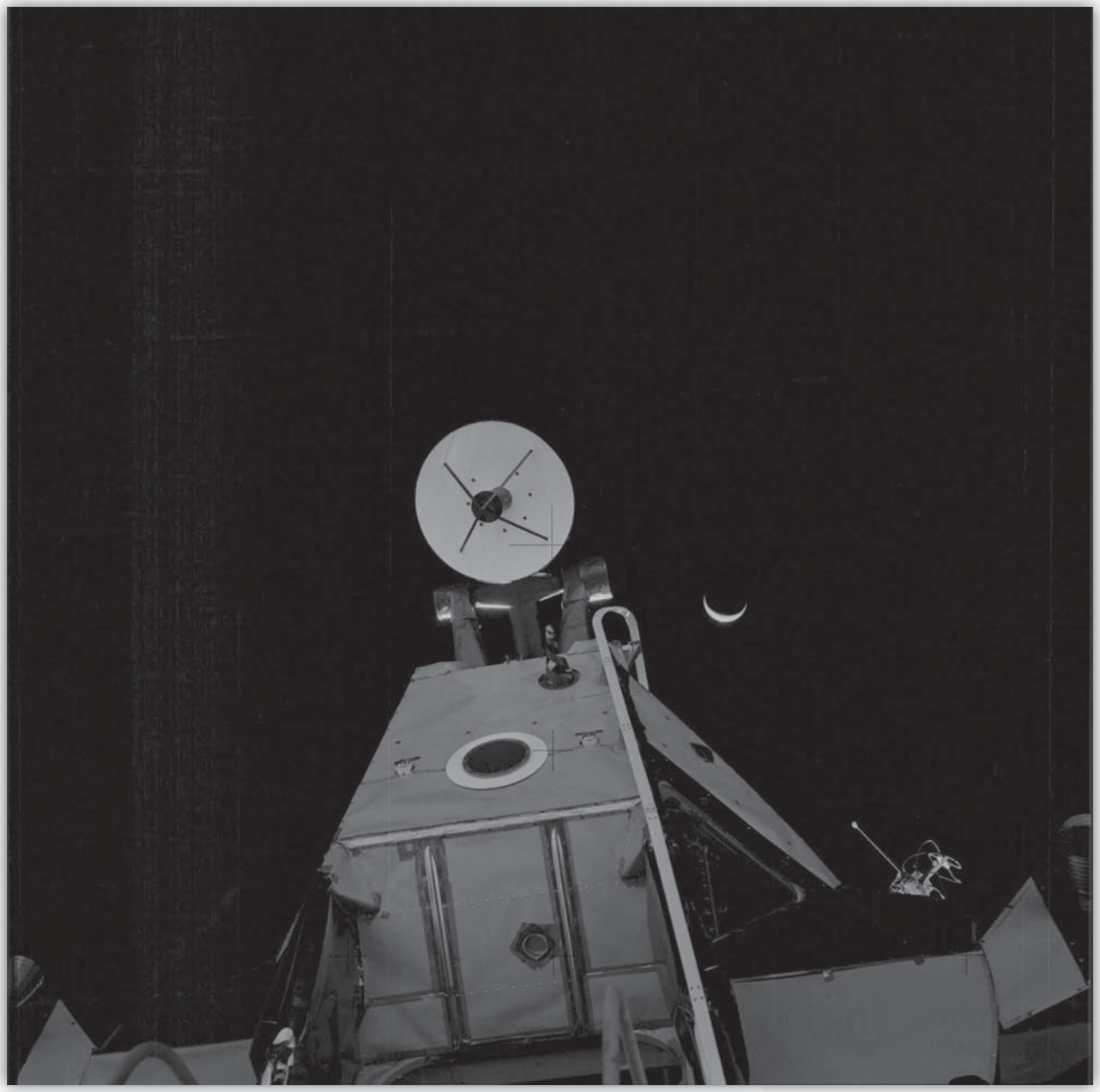


Figure 5.2-13. Photo AS14-64-9191 (Apollo 14). The upper stage of the Lunar Module, photographed by Alan Shepard on the Moon. The crescent in the sky is the Earth.

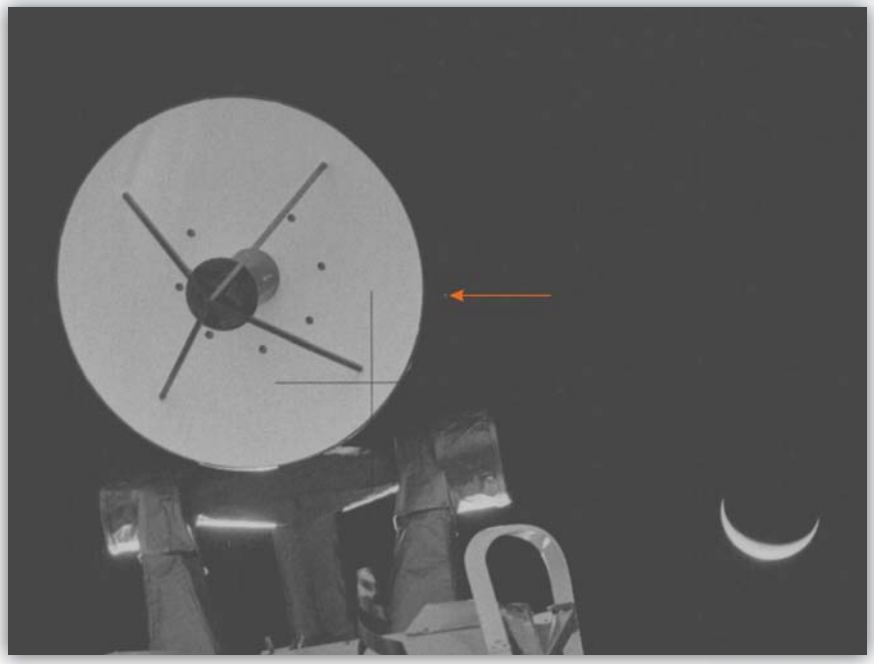


Figure 5.2-14. Detail of photo AS14-64-9191, enhanced and annotated to point out the planet Venus.

We know this is not a film defect because it appears in the same region of the sky in all three photographs and because astronomers have calculated that at the time when these picture were taken (23 April 1972 at 19:04 GMT/UTC) Venus indeed would have been visible from the Apollo landing site exactly in that position and direction.

Venus can also be spotted in some pictures taken by Alan Shepard during Apollo 14: it's that faint dot to the right of the lunar module antenna (Figures 5.2-13 and 5.2-14).

The faint presence of Venus in these Apollo photographs is another example of how difficult it would have been to fake the pictures: it would have been necessary to take into account even this kind of minute astronomical detail.

Further examples are available in *Photographing Stars* at the *Apollo Lunar Surface Journal*.

5.3 Why is the flag blowing in the wind on an airless Moon?

IN A NUTSHELL: *It's not blowing in any wind: it's hanging from a horizontal rod, because NASA figured out a limp US flag would not be cool.*

THE DETAILS: Some hoax theorists say that the American flag is fluttering in the wind in the Apollo photographs, as in Figure 5.3-1. But there's no air on the Moon. Therefore, they argue, the photographs are fake.

Actually, the flag *seems* to be fluttering because it's hanging from a horizontal rod, which is clearly visible along its top edge if the photographs are examined carefully. Figure 5.3-2 is a detail of Figure 5.3-1.



Figure 5.3-1. Apollo 11's flag. Photo AS11-40-5874.

NASA, not being dumb, realized well before the landings that on the airless Moon there would be no wind to make the flag wave, leading to a rather uninspiring droop, so this simple technical workaround was devised.

The flag also looks like it's wind-blown because of its billowed-out shape. But if you look carefully, you'll notice that it's crumpled and creased, rather than wavy as a wind-blown flag should be. It has sharp creases due to the fact that it was carried to the Moon tightly packed and folded in a casing attached to one of the legs of the lunar module. When the astronauts erected it on the Moon, they chose not to smooth out all of these creases, so that it would look like it was being proudly flown by the wind, like a traditional flag.



Figure 5.3-2. The horizontal rod that supports the flag. Detail of photo AS11-40-5874.

In some missions the telescopic horizontal rod didn't extend fully, so the upper edge of the flag remained gathered instead of being stretched straight. This brought out the creases even more and enhanced the remarkable illusion of a billowing flag.

Further evidence that the flag isn't fluttering in a draft on a movie set is that pictures taken at

different times (Figures 5.3-3, -4, -5 and -6) show that its shape never changes unless the astronauts touch it. The same crease pattern persists for tens of minutes, for example in the following stills from the Apollo 11 mission, showing that this fluttering is not caused by some draft or wind on a movie set.

Besides, why would the alleged makers of such an elaborate and crucially important important hoax make such an obvious mistake during filming? And why would they leave it in the published photos and film footage?

Moon hoax theorists also claim that the flag moves suspiciously in the live television and movie footage of the missions. These claims will be discussed in Chapter 6.



Figure 5.3-3. The Apollo 11 flag no longer moves after it has been positioned. This is a frame from the 16 mm film, taken just after the flag was planted.



Figure 5.3-4. Ten minutes after being planted, the flag is still identical.



Figure 5.3-5. Twenty minutes after being planted, the flag hasn't changed at all.



Figure 5.3-6. Thirty minutes after being planted, it's still unchanged.

5.4 How could the flag change position when the astronauts were back inside the spacecraft?

IN A NUTSHELL: *Because it was struck by the air vented from the cabin during depressurization and by the jets of the maneuvering motors during testing before taking off from the Moon.*

THE DETAILS: In some photographs of the Moon landings, such as those taken by Apollo 14, the US flag changes orientation although it hasn't been touched by the astronauts in the meantime. Who moved it?



Figure 5.4-1. Photo AS14-66-9325. The flag is oriented towards the Apollo 14 Lunar Module, from which the picture was taken at the end of Shepard and Mitchell's first lunar excursion, approximately at 119:42 mission elapsed time.

This anomaly can be noticed for example by comparing Apollo 14 photos AS14-66-9325 and -9339 (Figures 5.4-1 and 5.4-2), both taken from inside the Lunar Module after Ed Mitchell and Alan Shepard had ended their first and second explorations of the lunar surface. Photo 9325 was taken after the first EVA; 9339 was taken after the second one.

The visual record of the Apollo 14 moonwalks does not show the astronauts moving the flag after the first EVA, so the only possible explanation seems to be that someone else moved it by mistake. And since there was nobody else on the Moon, these photos appear to prove the hoax.

Actually, this phenomenon has a fascinating physical



Figure 5.4-2. Photo AS14-66-9339. At the end of the second EVA, the flag is pointing in the opposite direction.

explanation, which however is evident only to someone who is thoroughly familiar with the technology and the procedures of an Apollo mission.

Before exiting the Lunar Module to walk on the Moon, the astronauts had to depressurize the LM cabin by venting its air into the vacuum of space, using a valve located on the hatch. This air was therefore vented outside in the general direction of the flag, which after the first EVA was located approximately in front of the hatch.

This venting produced a cloud of gas which expanded rapidly, since in vacuum there was nothing to slow it or contain it, and therefore impinged on the flag, moving it.

The flag's movement was not hindered by any air resistance (since it was in vacuum), and therefore even a tiny difference in pressure between one side and the other was enough to move it.

There's also another counterintuitive phenomenon to be considered. Before leaving the Moon, the astronauts briefly test-fired the small rocket motors used for maneuvering. These motors were located in clusters in the upper part of the LM. These test firings, termed *RCS hot-fire checks,* were documented in the procedures and recorded on the onboard tapes. For Apollo 14, they can be found in the *Apollo 14 Lunar Surface Checklist*[1] on page 8-6 and in the *Return to Orbit section of the Apollo 14 Lunar Surface Journal*[2] at 149:49:50.

1
[http://tiny.cc/j0awoz]

2
[http://tiny.cc/jibwoz]

The nozzles of some of these thrusters happened to be directed towards the flag, and their gaseous exhaust expanded in vacuum, striking the flag and moving it.

These jets of gas were quite powerful: after the Apollo 14 test firings, Alan Shepard radioed that the large radio/TV dish antenna placed on the lunar surface had been blown over (its shadow can be seen in photo AS14-66-9339, but no longer in photo AS14-66-9339).

> 140:50:02 *Shepard: Okay. Here we go.* (Long Pause) *Okay, Houston. The* (S-band) *antenna blew over.*

In recalling the mission in the *Lunar Surface Journal* section cited above, Ed Mitchell noted that the firings shook the entire spacecraft.

> Jones - *"Tell me about that hot-fire check* [...] *Did it rock the LM at all?"*
>
> Mitchell - *"Oh, yeah"*.



Figure 5.4-3. A Russian Progress spacecraft fires its maneuvering thrusters as it approaches the International Space Station on 18 November 2018. Note the speed and size of their blast [http://tiny.cc/0nszbz].

The power of these thrusters of the Lunar Module can be better grasped by looking at current Russian Soyuz and Progress spacecraft, which have similar rocket motors for maneuvering. They can be seen in action in this video, taken from the approach of a Progress vehicle to the International Space station in November 2018.

5.5 Why are objects in shadow so strangely well-lit?

IN A NUTSHELL: *Because shadows on the Moon are not pitch-black as many people imagine them to be. Anything standing in shadow on the dayside of the Moon is still bathed in the glare from all the surrounding sunlit objects: the lunar surface, the Lunar Module, the bright white spacesuits.*

THE DETAILS: Moon hoax proponents argue that since the only source of light on the Moon is the Sun and there's no air to diffuse the light and soften the shadows, any object in shadow should be completely black.

But in Apollo photographs such as AS11-40-5869 (Figure 5.5-1), the astronauts are unexpectedly well-lit even when

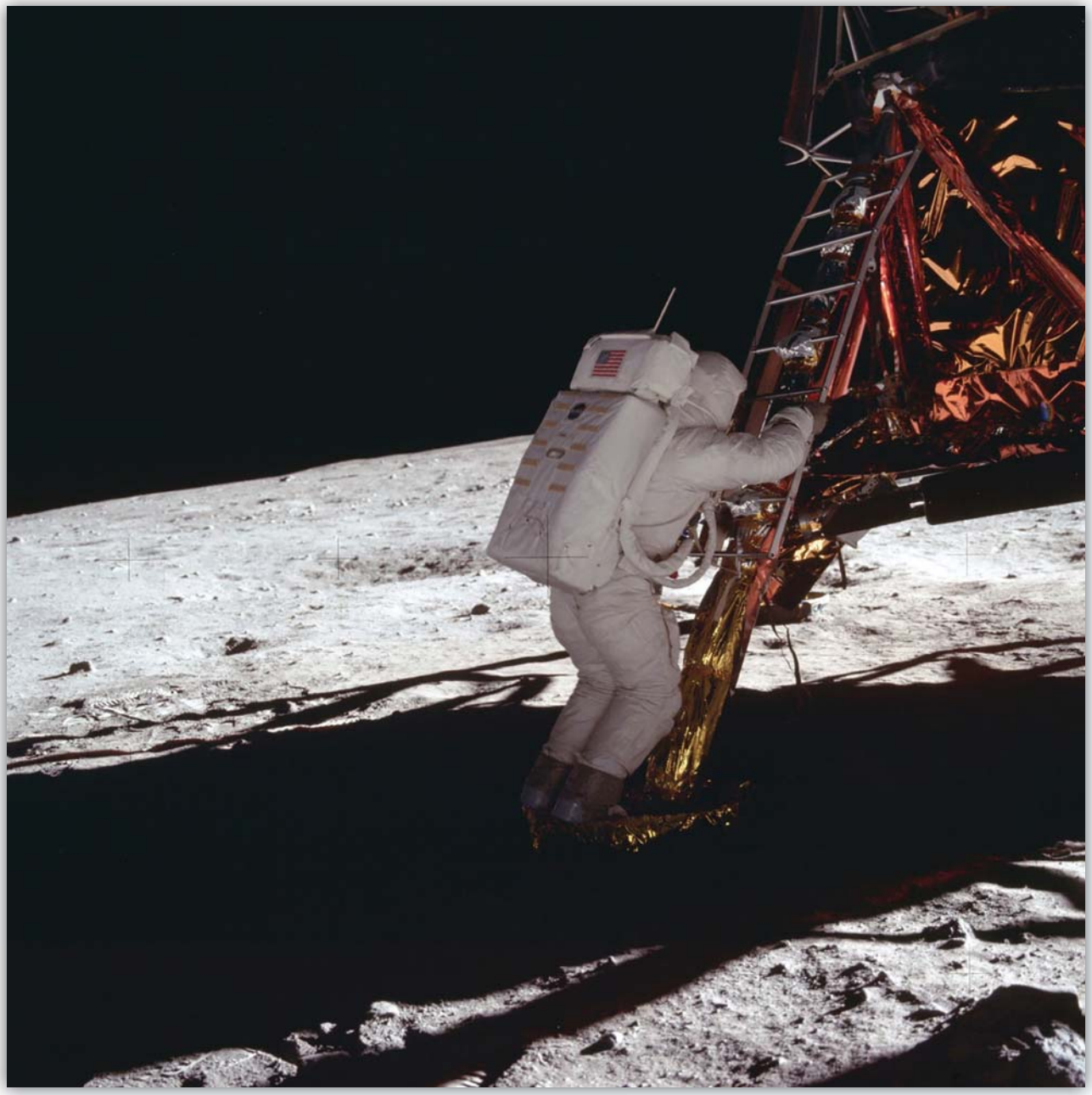


Figure 5.5-1. Buzz Aldrin on the LM footpad. NASA photo AS11-40-5869.

they're in the large shadow cast by the lunar module. Some conspiracy theorists say that this effect proves that studio lighting was used.

At first glance the picture does indeed seem strange and unnatural. But it's not because NASA used studio lights; it's because the natural lighting on the Moon is very different from our everyday experience. We're not used to a pitch-black sky in daytime; we're used to a bright sky that diffuses light. On the Moon, with no atmosphere to scatter sunlight and illuminate the sky, other lighting effects become more evident.

Aldrin's highly reflective white suit is simply lit by the sunlight reflected off the lunar surface all around him, which is in full daylight. It's quite a glare: although the Moon is only about as reflective as tarmac, the amount of light that it reflects is sufficient to make it shine so brightly in Earth's sky that it can be seen even in daylight. That reflected sunlight is what makes Aldrin visible. Anything rising above the lunar surface will be lit by the glare of the surrounding sunlit surface. The presence of an atmosphere has nothing to do with this effect.

There's also another significant source of reflected light close to Aldrin: his colleague, Neil Armstrong, who is standing up in front of him, in full sunlight, to take the photograph and is of course wearing a bright white spacesuit.



Figure 5.5-2. An Apollo 11 film magazine bears instructions for shadow photography ("full shadow-5.6"). Source: Smithsonian.

Of course, the light of the Sun reflected by the lunar surface towards anything that rises above it is not as bright as direct sunlight, so the astronauts simply set their cameras for shadow photography (note the reminder on the film magazine shown in Figure 5.5-2).

This means that in photos for which the camera was set for shadow any object in full daylight should be overexposed and washed out. Indeed, the sunlit lunar surface in Aldrin's photograph is nearly white instead of being its natural gray.

It's easy to demonstrate that the glare of the tarmac-like lunar surface is

sufficient to light an astronaut standing in shadow. All it takes is a model of the lunar module and of an astronaut, placed outside at night on a dark gray surface and lit by a single, powerful light source, with no nearby walls or objects that might reflect the light.

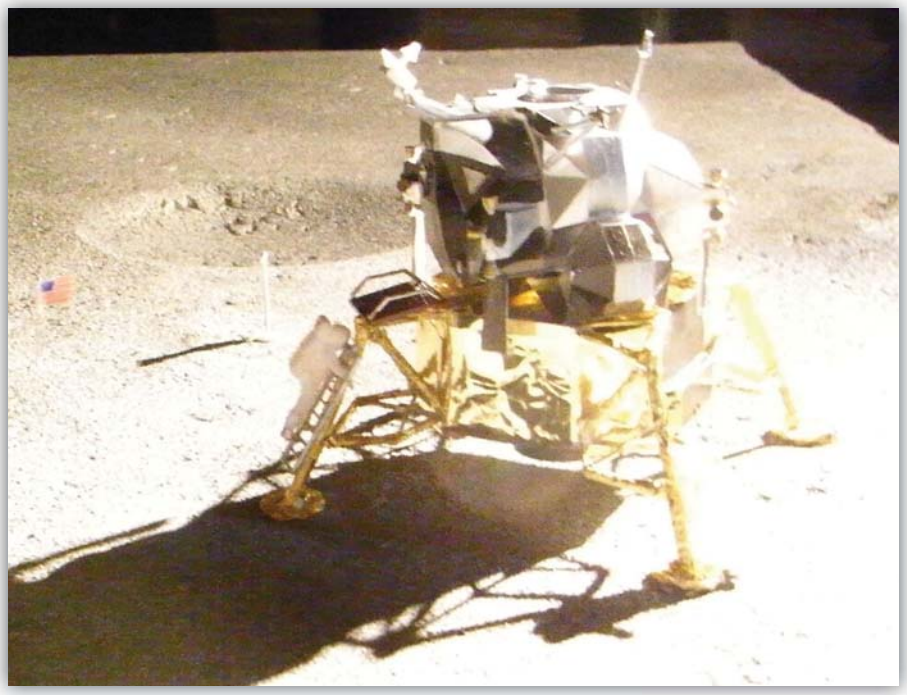


Figure 5.5-3. A model of a lunar landing scene, lit outdoors at night by a single light source. The astronaut in the shadow of the LM is visible. Credit: PA.

If you set the camera to take a good picture of the objects in the shadow of the LM, as shown in Figure 5.5-3, you get the same effect seen in Aldrin's photo: the astronaut on the ladder is well-lit by the light reflected off the simulated lunar surface, but the parts of the surface that are in direct "sunlight" are overexposed and almost white.

In other words, people who claim that this phenomenon reveals that the photographs were faked are actually revealing their lack of basic concepts of photography.

Besides, it's ultimately a matter of common sense: if astronauts were really not supposed to be visible when they stood in shadow on the Moon, then why would NASA make them so bright and get such an obvious detail wrong?

This conspiracy theory is a good opportunity to explain why all six Lunar Modules landed so that their hatch and ladder were in shadow. It's because Lunar Modules took care to keep the Sun behind them during their descent to the lunar surface, so that the shadow of the spacecraft would be visible through the front windows and would act as a reference to assess altitude. This was invaluable in an environment where there were none of the usual altitude references (houses, trees, roads) and there was no atmospheric haze to suggest distance.

5.6 Why aren't the shadows parallel?

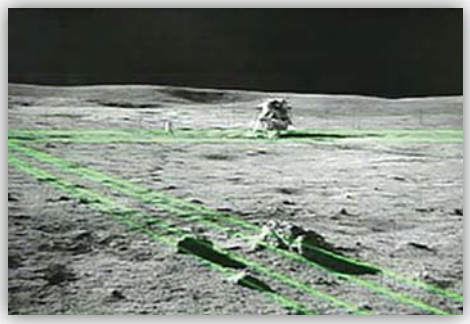


Figure 5.6-1. An Apollo photograph showing non-parallel shadows, as presented in the Fox TV show Did We Land on the Moon? *(2001).*

IN A NUTSHELL: *Because the shadows in the Apollo photographs actually* are *parallel when viewed from above, but perspective makes them appear to intersect when viewed from ground level. The same effect can be seen easily on Earth, for example in railroad tracks: their spacing only* appears *to change with distance, but it's actually fixed. Also, the lunar terrain is anything but flat, so shadows follow its contours and therefore appear to bend when viewed from the ground.*

THE DETAILS: If you trace the directions of shadows in many Apollo photographs, you'll notice that they're not parallel, as exemplified below.

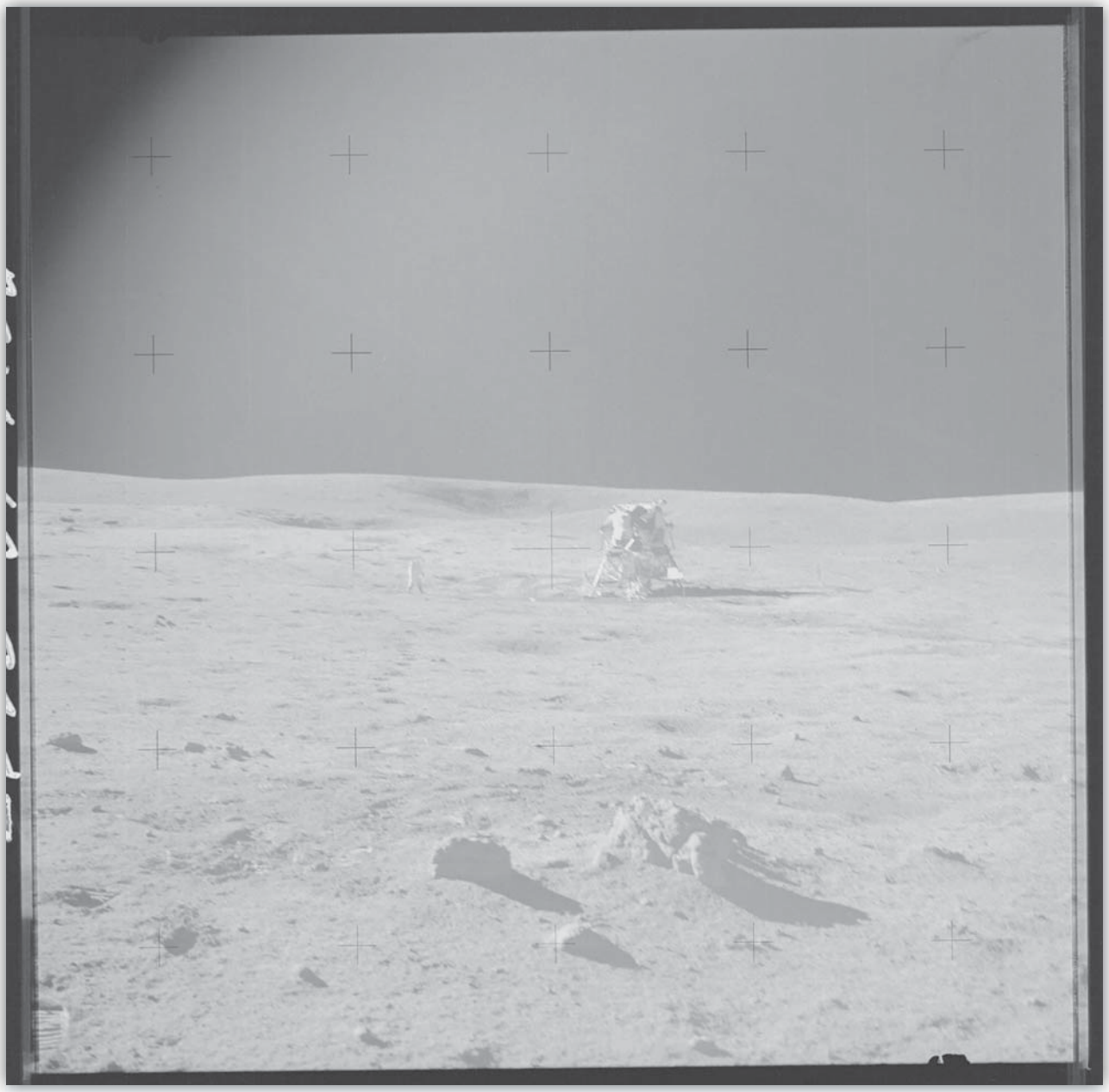


Figure 5.6-2. Photo AS14-68-9487 (Apollo 14) used by Fox TV to create the image shown in Figure 5.6-1 by cropping and drastically darkening the sky and the shadows.

Moon hoax proponents say that they should instead be parallel, because on the Moon there's only one light source (the Sun), which is very far away and therefore casts parallel shadows according to the rules of optics.

Bart Sibrel, in the Fox TV show *Did We Land on the Moon?*, states that *"Outside in sunlight, shadows always run parallel with one another, so the shadows will never intersect"*.

As usual, the conspiracy theorist presents the photograph without identifying it. It takes some research to determine that it's photo AS14-68-9487 (Figure 5.6-2), taken during the Apollo 14 mission.

Intersecting shadow directions, it is argued, imply multiple light sources, which are impossible on the Moon and suggest studio lighting. No explanation is given by Moon hoax proponents as to why NASA or the alleged hoax perpetrators would have made such a colossally stupid and glaring mistake.

In actual fact, multiple light sources would cause each object to cast *multiple* shadows, as occurs with the players in a football or baseball match played at night. But in the photographs taken on the Moon each object casts only one shadow.

Sibrel is correct in stating that in sunlight shadows run parallel to each other, but he seems to have forgotten about *perspective*, which causes the directions of shadows that are actually parallel to *appear* to intersect if viewed or photographed from most angles. It's a basic optical principle that occurs on Earth as well: parallel objects, such as railroad tracks, appear to converge in the distance, but they don't actually become closer or intersect. That would make it rather hard for trains to work.

This perspective effect is really easy to demonstrate in real life. The photo shown in Figure 5.6-3 shows shadows cast at sunset by trees and by my very patient wife Elena. The sun is on the right. From this angle, the shadows look essentially parallel, as indeed they were when I took this picture.



Figure 5.6-3. My wife Elena patiently stands in for a lunar astronaut. Credit: PA.



Figure 5.6-4. The same shadows as in the previous photograph, taken from a different angle, now appear to converge. Credit: PA.

But if the same scene is photographed a few seconds later from a different angle, as in the photo shown in Figure 5.6-4, the directions of those very same shadows suddenly appear to intersect, converging away from the viewer. However, it's just an optical illusion caused by perspective. The shadows haven't actually moved.

In other words, anyone who claims that intersecting shadows in Apollo photos are evidence of studio fakery merely shows a lack of understanding of the very simple concept of perspective and reveals very limited powers of observation. All it takes to realize that this claim is bogus is to go outside and look around.

However, perspective is not the only phenomenon that can alter the direction of shadows in photographs: the uneven shape of the ground can also produce the same effect. In the photos taken on the Moon there are no familiar objects that can be used as reference, such as plants or roads or houses, and the ground is very uniform in color, so it's hard to detect any rises or hollows. The observer tends to assume that the ground is level even when it isn't, and this alters perception.



Figure 5.6-5. Mythbusters *creates a simulation of the lunar environment and of its shadows, changing the directions of the shadows by creating a local rise [http:tiny.cc/83szbz].*

For example, in the specific case of photo AS14-68-9487 shown above, at first glance the rocks in the foreground seem to stand on a level surface, but they're actually perched on a small rise. Accordingly, their shadow falls onto the slope of this rise and changes direction, as demonstrated by the TV show *Mythbusters* starting from this very photograph.

The fact that these rocks stand on a rise and that the surface is anything but level becomes perfectly evident by creating an *anaglyph* (3D image) based on photos AS14-68-9486 and -9487, taken from slightly different points, as Kevin Frank did for the *Apollo Lunar Surface Journal* (Figure 5.6-6).

This phenomenon is fairly easy to replicate on Earth. For example, Figures 5.6-7 and 5.6-8 show toothpicks lit by sunlight. Seen from above, they cast essentially parallel shadows. Seen from the side, however, they cast intersecting shadows which converge *toward the viewer* instead of being parallel or converging on the horizon. I took the photos myself in my garden with an ordinary mobile phone, using the sun as the only light source, just like on the Moon.

This effect is due to the fact that the toothpick on the right is on a rise of the surface. This rise is not noticeable because its shape is masked by the fine crushed rock I used to create

the simulated lunar surface texture. But if this pulverized rock is removed, as in Figure 5.6-9, the actual shape of the surface becomes evident: the shadow's direction is altered by the slope of the terrain.

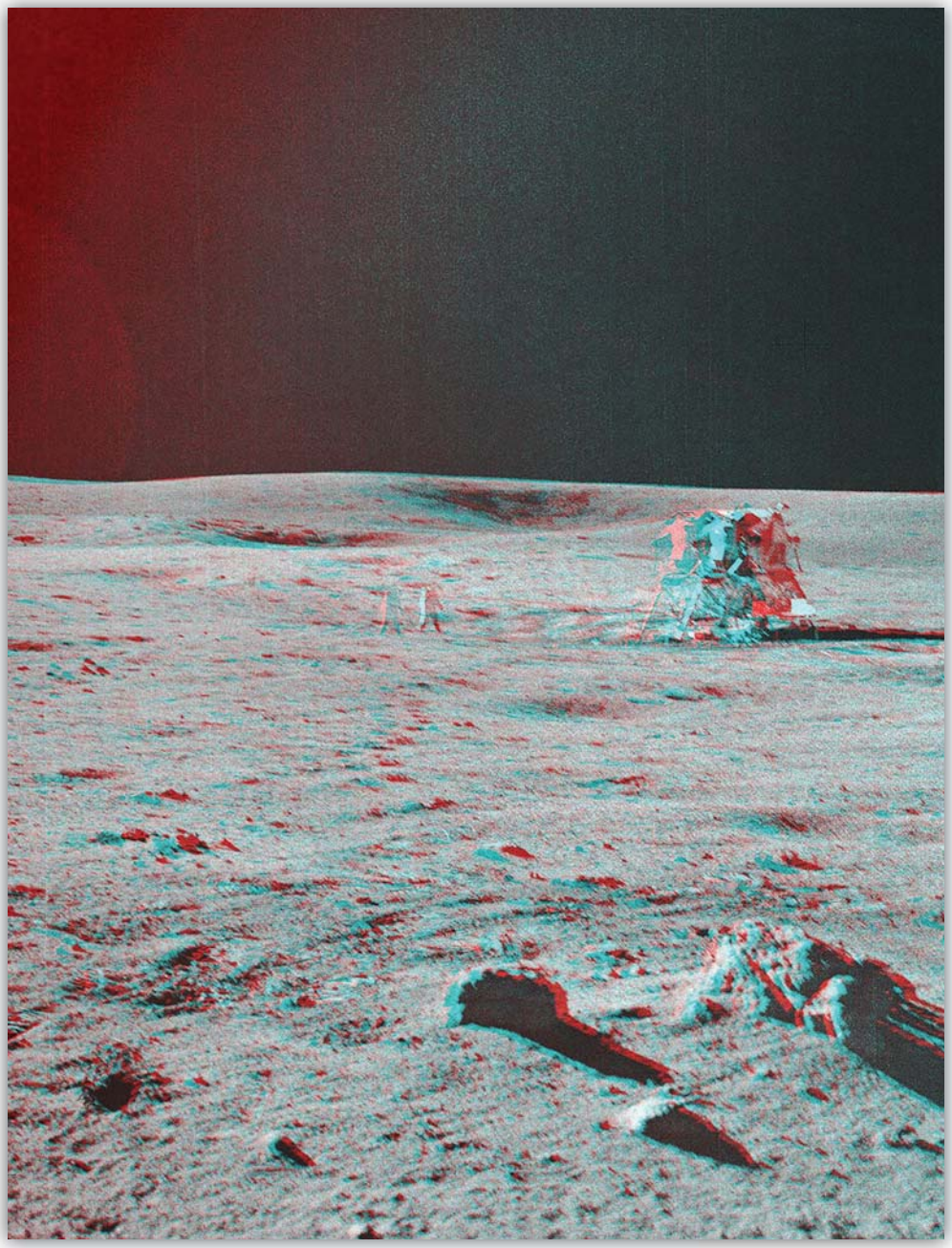


Figure 5.6-6. Photos AS14-68-9486 and -9487, combined by Kevin Frank into a 3D anaglyph, reveal that the foreground rocks stand on a rise which is otherwise hard to notice. Glasses with red and blue filters are required to view the 3D effect.



On the left: Figure 5.6-7. Toothpicks planted in a rough simulation of lunar terrain, seen from above, cast parallel shadows. Credit: PA.



On the right: Figure 5.6-8. The shadows of the same toothpicks, seen from the side, converge toward the viewer instead of diverging or being parallel. Credit: PA.



On the left: Figure 5.6-9. The toothpicks of Figures 5.6-7 and 5.6-8 without the pulverized rock texture on their supporting surface. Credit: PA.



http://tiny.cc/vctzbz

On the right: Figure 5.6-10. Converging shadows produced by the shape of the terrain, which is hidden by the pulverized rock and then revealed Credit: PA.



http://tiny.cc/ddtzbz

5.7 Why do the astronauts cast shadows of different lengths?

IN A NUTSHELL: *Because the Moon's surface isn't perfectly smooth and level. If there's a slope, a bump or a hollow in the ground, the astronaut's shadow will follow its shape and vary its length accordingly. The same happens on Earth.*

THE DETAILS: In some Apollo photos and movies the shadows of the astronauts have quite different lengths; an example is shown in Figure 5.7-1.

Moon hoax proponents such as David Percy argue (for example on the Aulis.com website) that this is because the fake astronauts stood at different distances from the overhead studio lights.

> *An explanation for this anomaly is that the two men are standing in such close proximity to a large artificial light source that as either one moves nearer to or further away from this light, the shadow of each astronaut changes accordingly.*

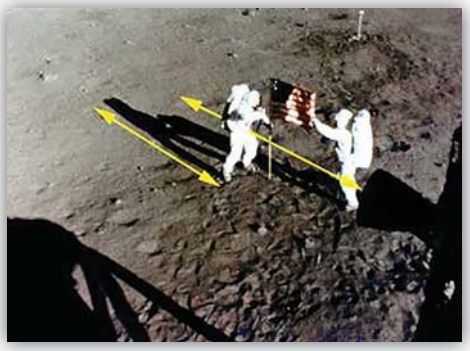


Figure 5.7-1. A frame from the Apollo 11 movie camera shows that the shadows of the astronauts have different lengths. Source: Aulis.com.

As usual, the first problem with this theory is that the creators of the fakery would have to be incredibly dumb not to notice a technical mistake of this magnitude and hope to get away with it.

However, Percy's explanation doesn't hold water, because in the image above the astronaut who is closest to the hypothetical spotlights (as indicated by the direction of the shadows) has the longest



Figure 5.7-2. A model shows how even a small hollow changes shadow lengths. Credit: PA.

shadow, whereas in real life objects that are closer to an elevated light source cast *shorter* shadows. This can be demonstrated easily by standing at various distances from a streetlight.

The correct explanation for the different shadow lengths is that the surface of the Moon is uneven and has all sorts of slopes, rises and hollows, which sometimes aren't easily detected in photographs because there are no familiar items for visual reference. These differently sloping portions of the surface alter the length of any shadow that falls onto them. The same thing happens on Earth.

This can be shown by building a model of the lunar surface and lighting it with direct sunlight. It turns out that a model astronaut placed even in a shallow depression casts a shadow which differs greatly in length from the one cast by another identical model astronaut standing on level ground, as shown in Figure 5.7-2.

In the Apollo 11 image disputed by Percy and Aulis.com (Figure 5.7-1), the astronaut on the left is simply standing in a slight hollow of the ground, which shortens his shadow. The effect is particularly conspicuous because the Sun is low on the horizon and therefore all shadows are very long.

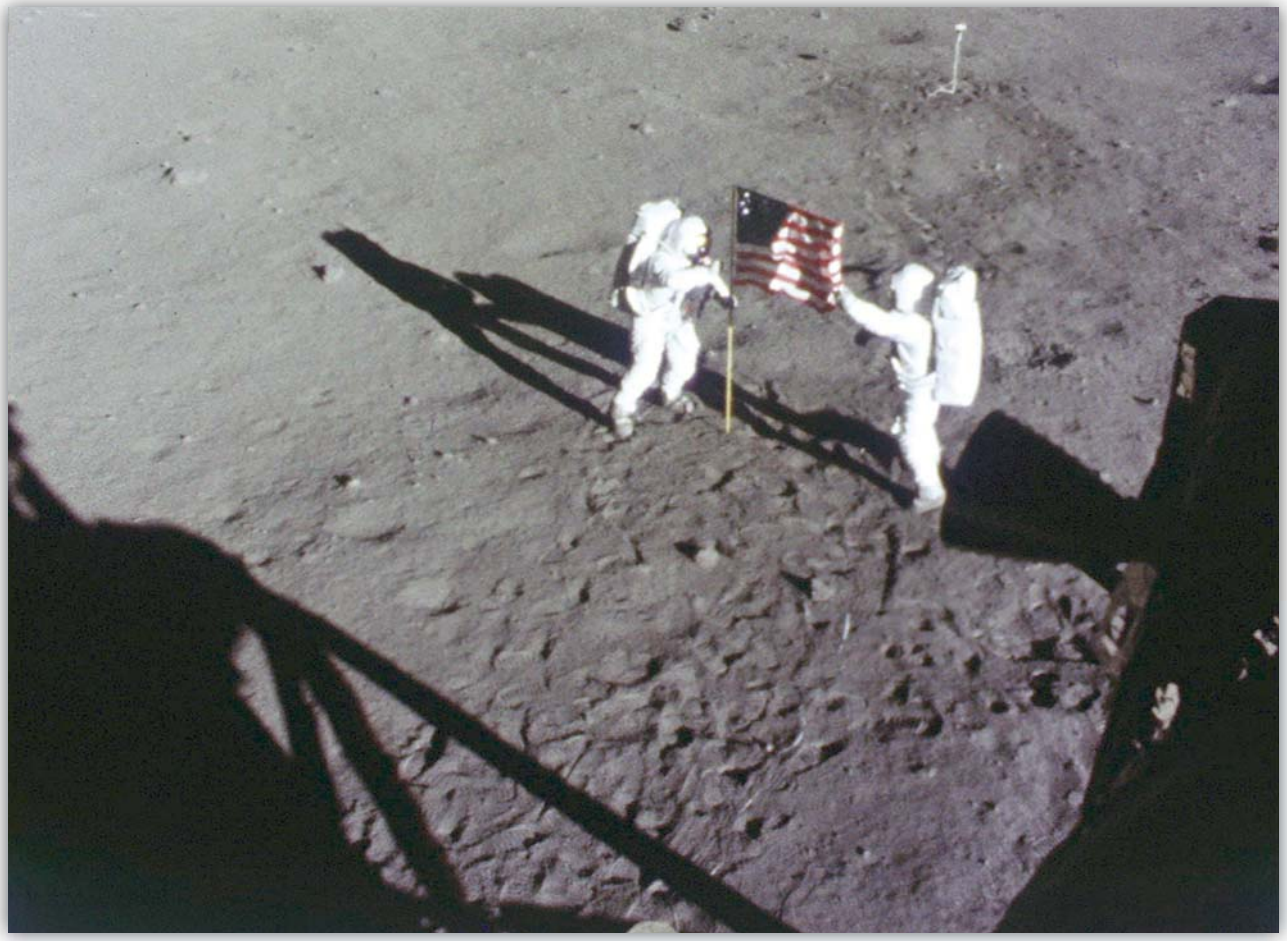


Figure 5.7-3. A sharper copy of the 16mm film frame shown in Figure 5.7-1.

This hollow isn't detectable in the Aulis picture, but it's definitely there: it's revealed by the curved shadow of the flagpole in photo AS11-37-5473 (shown cropped for clarity in Figure 5.7-4).

What's surprising is that Percy is a member of the British Royal Photographic Society and has received several awards for his work as cameraman. In theory, therefore, he should be quite knowledgeable about lighting and the behavior of shadows on uneven ground.

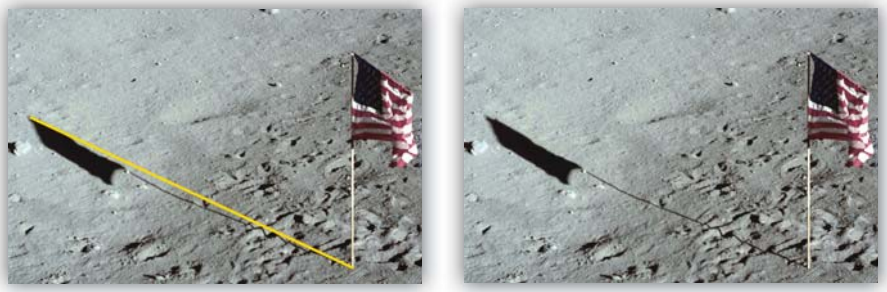


Figure 5.7-4. Detail of photo AS11-37-5473 (Apollo 11).

5.8 How come the shadow of the LM reaches the horizon?



Figure 5.8-1. Detail of photograph AS11-40-5931 (Apollo 11).

IN A NUTSHELL: *That's not the horizon. It's the raised rim of a nearby crater that hides the actual horizon, which is a lot farther away.*

THE DETAILS: In photograph AS11-40-5931 (Apollo 11), shown in Figures 5.8-1 and 5.8-2, the shadow of the Lunar Module appears to extend all the way to the horizon.

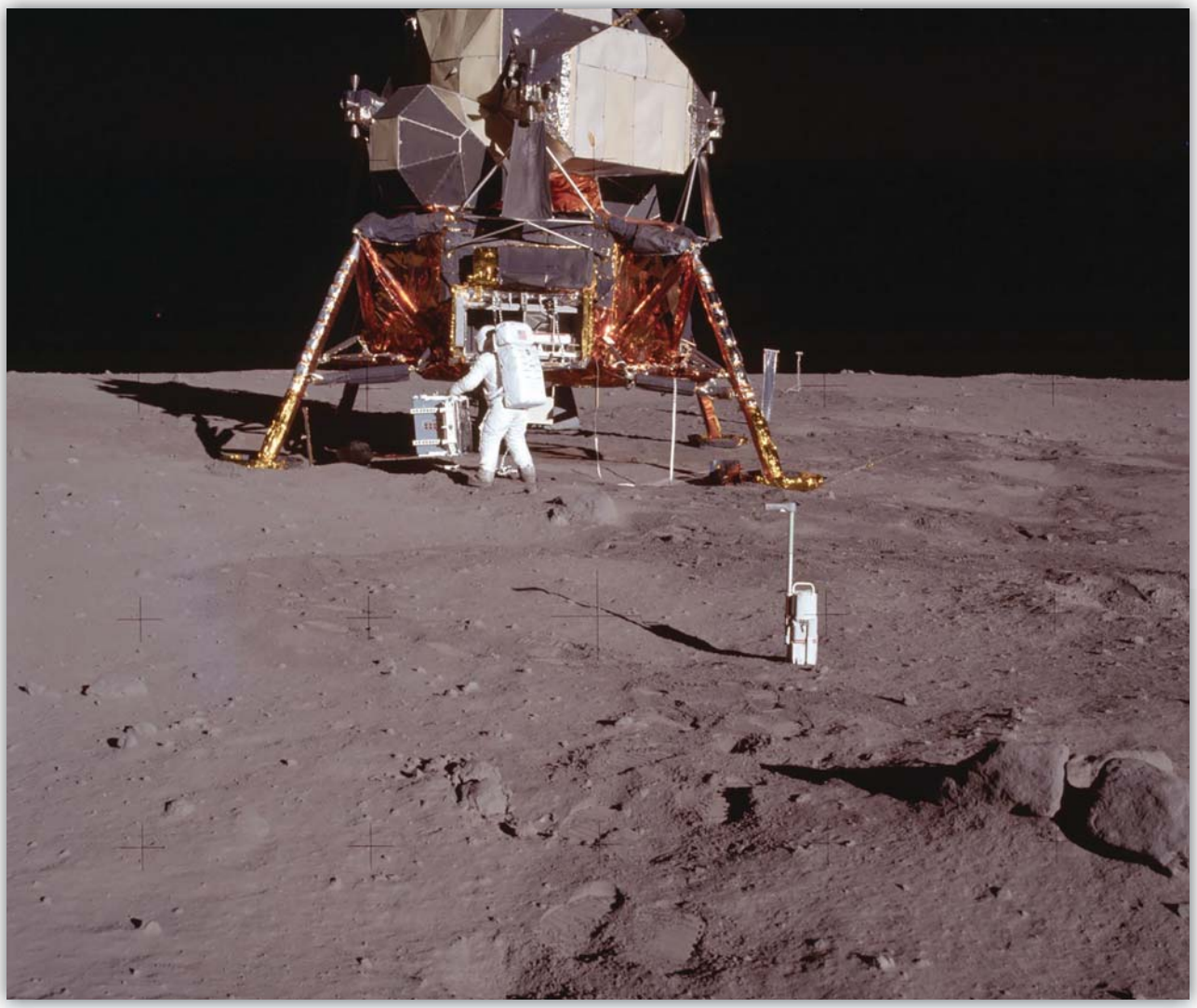


Figure 5.8-2. The full frame of AS11-40-5931.

Moon hoax theorists such as Bill Kaysing argue that this makes no sense: the horizon should be miles away. For them it proves that the picture was taken on a small movie set and that the "horizon" is actually the line where the black backdrop that faked the sky met the edge of the set floor.

However, if we look at AS11-40-5961 (Figure 5.8-3), another photograph of the same location taken from a greater distance in roughly the same direction, we can see that the shadow of the LM actually doesn't reach the horizon at all. Moreover, this photo shows that the alleged "movie set" would have had to be huge.

If we check the astronaut traverse map of Apollo 11 (Figure 5.8-5), we find that the LM landed close to



Figure 5.8-3. Photo AS11-40-5961 (Apollo 11). The shadow on the left belongs to Neil Armstrong, who is taking the photograph; the thin diagonal shadow on the right belongs to the ALSCC camera.

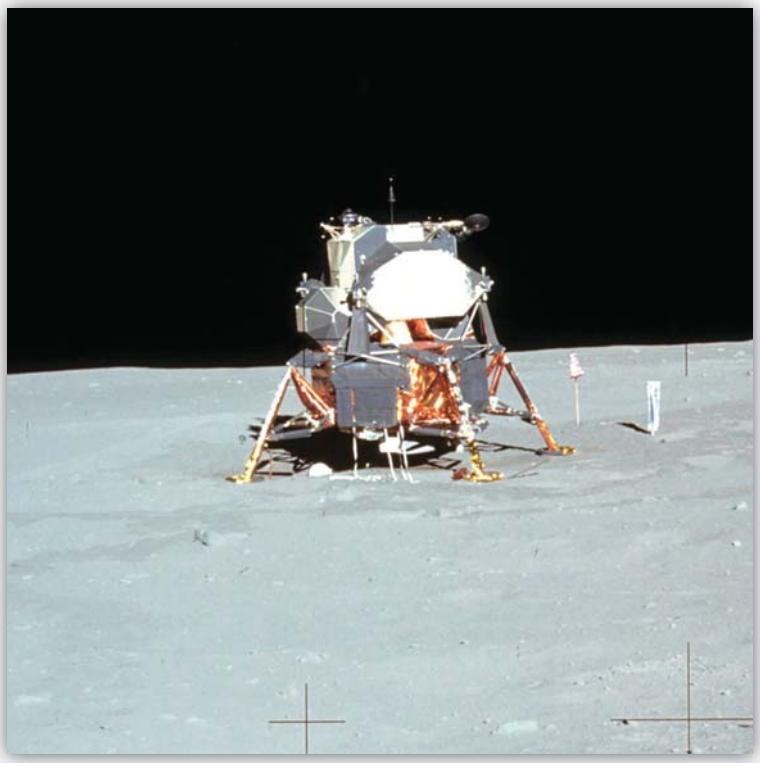


Figure 5.8-4. Detail of AS11-40-5961.

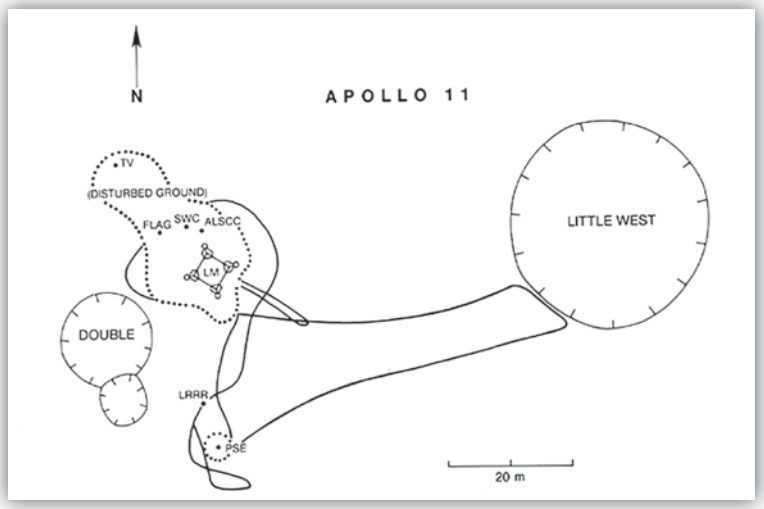


Figure 5.8-5. Apollo 11 traverse map. LM - Lunar Module; LRRR - Laser Ranging Retroreflector; PSE - Passive Seismic Experiment; SWC – Solar Wind Composition; ALSCC Apollo Lunar Surface Closeup Camera; FLAG – US flag.

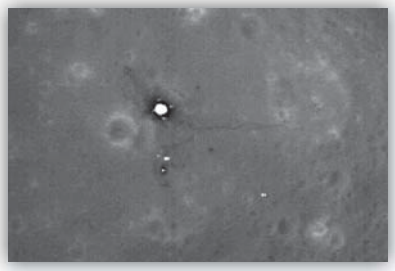


Figure 5.8-6. Image of the Apollo 11 landing site taken by the Lunar Reconnaissance Orbiter in 2009.

two fairly large craters, dubbed *Double* and *Little West*, and that Double crater, approximately 15 meters (50 feet) in diameter, is located about 10 meters (30 feet) from the spacecraft. These craters are also documented in the photographs taken by the Lunar Orbiter probes in 1967, two years before the Apollo 11 landing (for example in photo V-76-H3).

In Figures 5.8-3 and 5.8-4, which show a photograph taken with Little West crater behind the photographer, Double crater is in the left part of the background. It owes its rather unimaginative name to the fact that it's actually composed of two craters. In the map shown in Figure 5.8-5, the photograph of Figure 5.8-3 and 5.8-4 is taken from the right with the camera pointing left.

We can also inspect the landing site in the photographs taken by the Lunar Reconnaissance Orbiter and acquired in 2009 (Figure 5.8-6): Double crater is on the left of the LM, which is the large white spot at the center, surrounded by four darker dots which are the LM's footpads. The white spots in the lower region of the photograph are the instruments left on the Moon by Armstrong and Aldrin. The orientation of this photograph matches the orientation of the map shown in Figure 5.8-5.

Putting together all this information, it turns out that the "horizon" claimed by hoax theorists is not the horizon at all: it's the raised ridge of Double crater, which hides the actual horizon. The crater's rim is highlighted in Figure 5.8-7.

The view from the LM and the unevenness of the terrain in front of the spacecraft are clearly shown by the panoramic composite picture of Figure 5.8-8, which

combines Hasselblad photographs and 16 mm film frames taken from inside the LM.

In other words, there's nothing wrong with the shadow of the LM, which does not reach the horizon at all. Conspiracy theorists who make this claim wrongly assume that the Moon is a perfectly smooth sphere and forget to consider that it has hollows and rises which can hide the true horizon. Many conspiracy theories are based on this incorrect assumption.

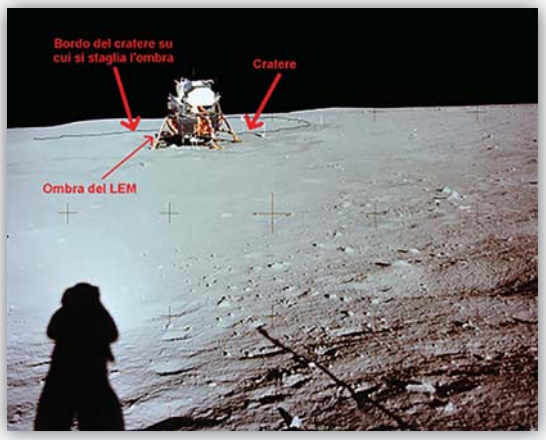


Figure 5.8-7. Photo AS11-40-5961, annotated to outline the edge of Double crater. Credit: Siamoandatisullaluna.com, with the authors' permission.

Incidentally, on the Moon the horizon is much closer to the observer than on Earth because the Moon is a smaller world. Barring any valleys, hills or mountains, the lunar horizon is about 2.43 kilometers (1.5 miles) from an observer whose eyes are 1.7 meters (5 feet 7 inches) above the ground. On Earth, for that same observer the horizon is about 4.7 kilometers (3 miles) away. From the point of view of the cameras mounted on the astronaut's chest bracket, about 1.5 meters (4 feet 11 inches) above the ground, the lunar horizon would be even closer: just 2.28 kilometers (1.41 miles).



Figure 5.8-8. Panoramic composite view of the lunar surface in front of the Apollo 11 LM. Credit: R. Farwell.

5.9 Why is there no flag shadow in the salute photograph?

IN A NUTSHELL: *Because the shadow of the flag fell out of the frame due of the shallow Sun angle, but it can be seen in other photographs and in the TV and 16 mm footage. The shadow of the* flagpole *is visible in high-quality scans of the salute photo.*

THE DETAILS: The famous photograph of Buzz Aldrin's salute to the first American flag on the Moon (AS11-40-5874, shown in Figure 5.9-1) is often alleged to be a fake because the shadow of the flag is missing. The missing shadow, it is claimed, proves that the flag was added later. In this photograph, the light source is on the left and therefore the shadow of the flag should lie to the right of the flag itself, but it's nowhere to be seen.

Sometimes the claim is boosted by showing another photograph, taken seconds later (AS11-40-5875, Figure 5.9-2), in which Aldrin hasn't raised his arm to salute and therefore appears to be simply standing on the lunar surface, staring into nothingness as if the flag were not there.

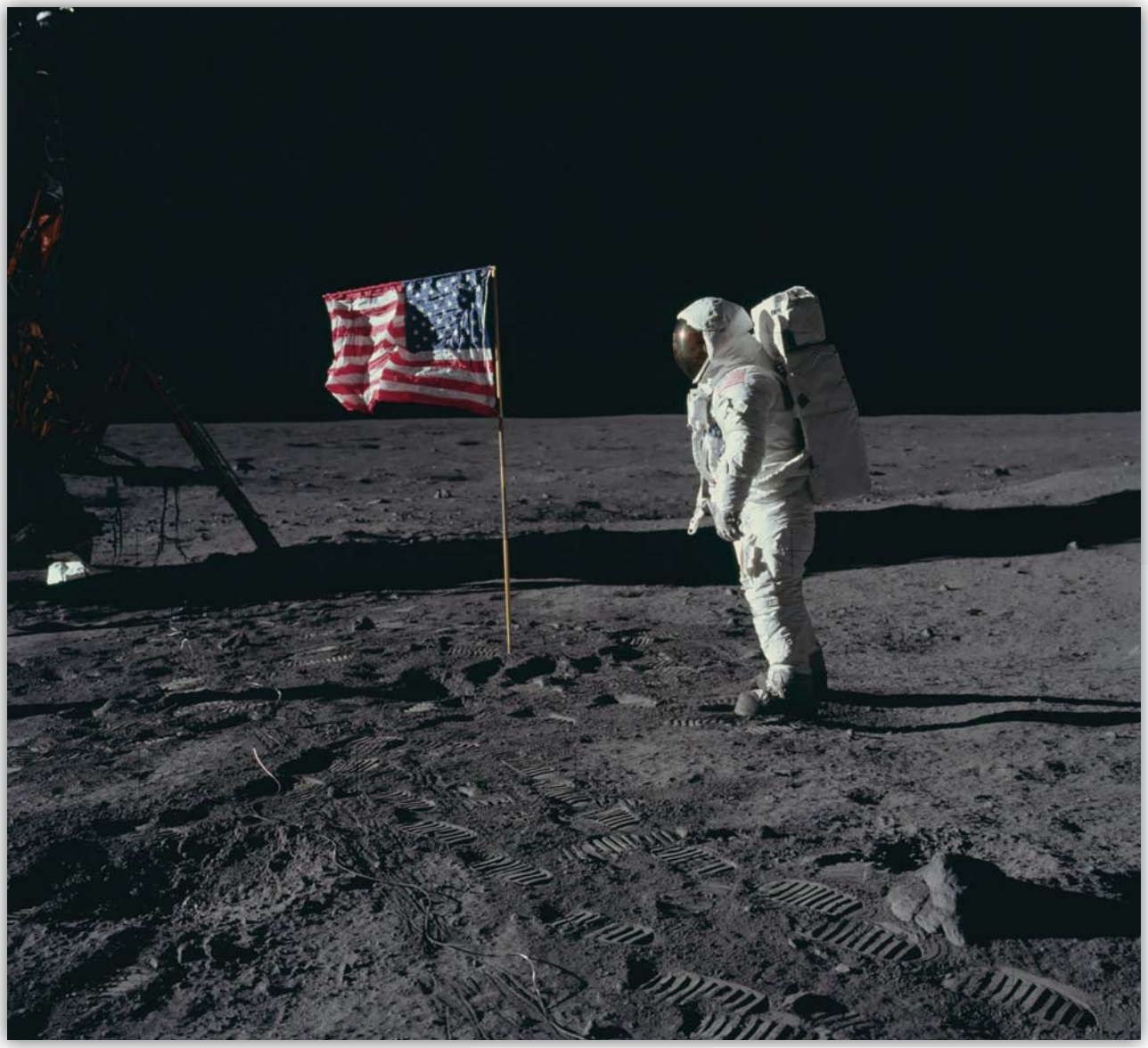
However, there are logical flaws in the claim that the flag was added and the fakers forgot to add its shadow. First of all, how could the fakers possibly have forgotten to take such an iconic image as a salute to the Stars and Stripes? And if they faked it, why would they have been so spectacularly dumb as to forget to add the flag shadow?



Figure 5.9-1. Photograph AS11-40-5874 (Apollo 11): Buzz Aldrin salutes the Stars and Stripes on the Moon.

Secondly, if the photos were faked in a studio, why would it have been necessary to add the flag by using poorly done cut-and-paste trick photography? It would have been easier to go back to the studio and take a few more photos with the flag in place.

Thirdly, there is TV and 16 mm film footage of Aldrin's salute to the flag. So why risk exposure by faking two photographs of the salute, when there are video and color movie records of this historic moment?



Above: Figure 5.9-2. Photo AS11-40-5875: Buzz Aldrin standing on the Moon next to the US flag (slightly cropped).



Figure 5.9-3. An excerpt from the Apollo 11 live TV broadcast [http://tiny.cc/m1tzbz].

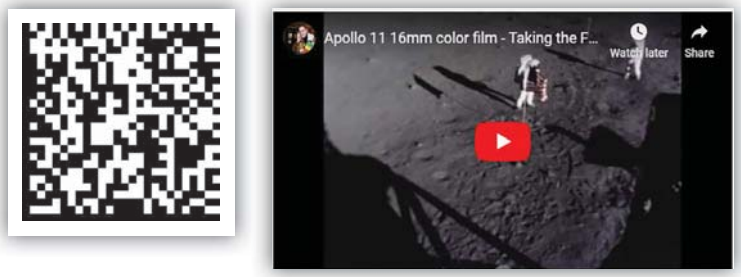


Figure 5.9-4. Apollo 11 film footage of the flag salute, recorded by the LM-mounted 16 mm camera at the rate of one frame per second [http://tiny.cc/g3tzbz].

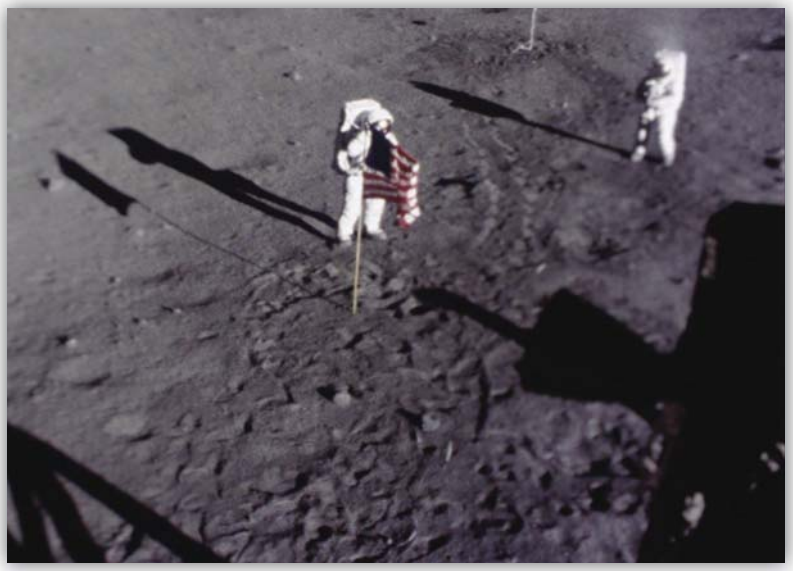


Figure 5.9-5. A frame from the 16 mm film shows Aldrin's salute. Aldrin is behind the flag, with his right arm is raised in salute, as evidenced by the arm's shadow. Armstrong is in the upper right corner, taking photographs. The white vertical rod at the top margin is the TV camera tripod. The large dark region on the right is the silhouette of the Lunar Module, which partly covers the shadow of the solar wind experiment (the vertical rectangle on the left in the live TV broadcast).

These two recordings allow to reconstruct the scene in detail and check the perfectly matching positions of the shadows, of the rocks and of other details of the terrain. The 16 mm footage very clearly includes the shadow of the flag and of its pole.

This reconstruction allows to determine the very simple reason why the shadow of the flag is missing in the two photographs: it lies outside the viewing field of the camera, beyond the right margin of the picture, because the Sun was low on the horizon and therefore all the shadows were very elongated. Calculations and documents indicate that the elevation of the Sun above the horizon, at the Apollo 11 landing site between July 20 and 21, 1969, ranged from 14° to 15.4°.

The shadow of the flag falls off camera, but what about the shadow of the *flagpole*? It turns out that it actually *is* visible in the photos, as it should be, but only in their high-quality scans (Figure 5.9-6): it's the thin dark line behind the astronaut's legs, roughly at ankle height. The rod was only about 2.5 centimeters (1 inch) thick, so it cast a very thin shadow, especially when viewed sideways as in the photograph in dispute.

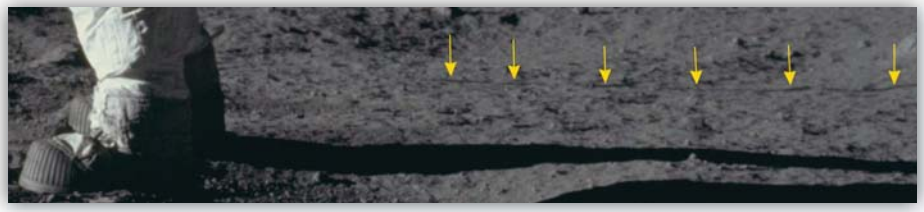


Figure 5.9-6. Annotated detail of AS11-40-5874 (Apollo 11). The very thin shadow of the flagpole is faintly visible above the shadow of Aldrin's legs, running horizontally across.

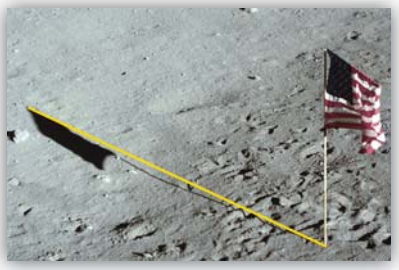


Figure 5.9-7. This detail of photo AS11-37-5473 (Apollo 11) clearly shows the hollow in the ground into which the pole and flag shadows are cast.

The flagpole shadow is rather hard to locate because it's not where you expect it to be, i.e., at the same level as the base of the pole: a shallow depression in the ground bends it, so it's further down. The depression in which the shadow of the flagpole falls is shown in Figure 5.9-7. This is the same hollow that alters the length of the astronauts' shadows, as described in Section 5.7, *Why do the astronauts cast shadows of different lengths?*

5.9.1. Stereoscopic evidence

As further verification, since the two photographs (5874 and 5875) were taken by Neil Armstrong from two slightly different positions, they can be used to create a stereo image and check that the flag is not simply added but is actually on the correct plane of depth within the scene.

The 3D placement of the flag is correct and consistent in the two photographs. Anyone attempting to fake these images would have had to include this detail. This is another example of how hard it would have been to create a fake.

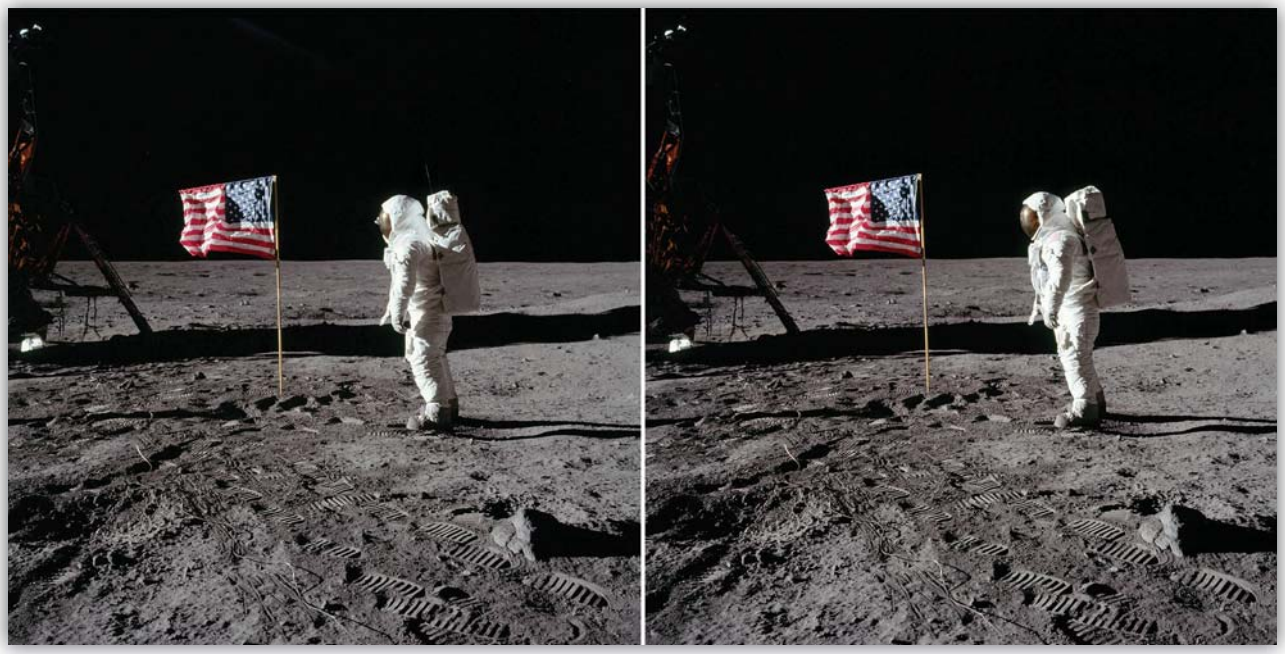


Figure 5.9-8. Photos AS11-40-5874 and 5875, placed side by side for cross-eyed stereo viewing.

5.9.2. What is Aldrin looking at?

Leaving conspiracy theories aside for a moment, all this cross-checking reveals a nice detail: in AS11-40-5875, Aldrin isn't staring into nothingness, but he's *looking into the camera*. This is clearly noticeable in the enlarged detail views shown in Figure 5.9-9: the outlines of Aldrin's face are clearly identifiable, and so is the white path of the

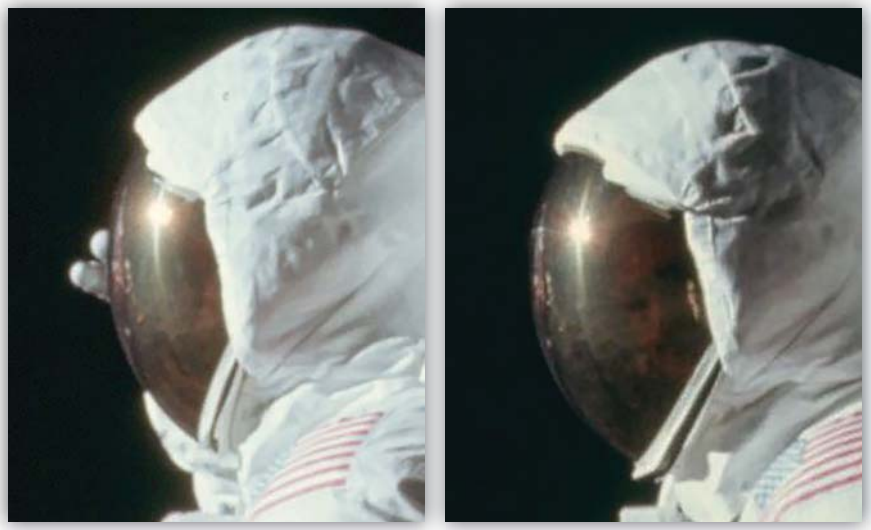


Figure 5.9-9. Aldrin salutes the flag and then turns to the camera in these details from photos AS11-40-5874 and 5875.

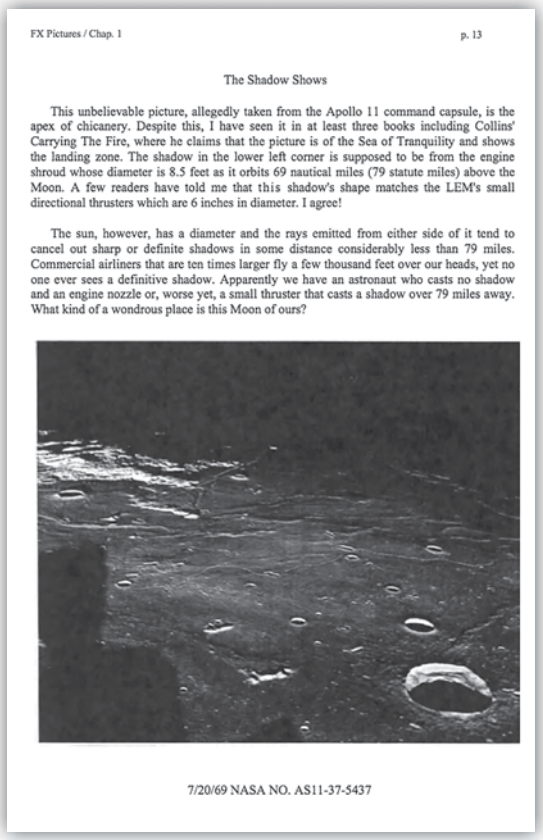
"Snoopy cap", the soft cap that contained the astronaut's headset and microphones for radio communications.

There are very few photographs of the lunar astronauts in which their faces can be seen. Their features were usually hidden by the reflective gold visor, which was raised only occasionally in order to avoid dazzling and overheating. This is an even rarer event, since the visor is lowered but Aldrin's face is in full sunlight and therefore receives enough light to become visible even through the thin gold coating of the visor.

5.10 How come the spacecraft casts an impossibly huge shadow?

IN A NUTSHELL: *It doesn't. That's not the shadow of the Apollo vehicle cast on the lunar surface, it's the close-up silhouette of one of its small maneuvering thrusters.*

THE DETAILS: On page 13 of his book *NASA Mooned America!*, Ralph Rene shows a photograph that he describes as *"the apex of chicanery"*. He claims that it shows, in the lower left corner, *"the shadow* [...] *from the engine shroud whose diameter is 8.5 feet* [2.6 meters]*"* or from one of the LM's *"small directional thrusters which are 6 inches* [15 centimeters] *in diameter"*.



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The Shadow Shows

This unbelievable picture, allegedly taken from the Apollo 11 command capsule, is the apex of chicanery. Despite this, I have seen it in at least three books including Collins' Carrying The Fire, where he claims that the picture is of the Sea of Tranquility and shows the landing zone. The shadow in the lower left corner is supposed to be from the engine shroud whose diameter is 8.5 feet as it orbits 69 nautical miles (79 statute miles) above the Moon. A few readers have told me that this shadow's shape matches the LEM's small directional thrusters which are 6 inches in diameter. I agree!

The sun, however, has a diameter and the rays emitted from either side of it tend to cancel out sharp or definite shadows in some distance considerably less than 79 miles. Commercial airliners that are ten times larger fly a few thousand feet over our heads, yet no one ever sees a definitive shadow. Apparently we have an astronaut who casts no shadow and an engine nozzle or, worse yet, a small thruster that casts a shadow over 79 miles away. What kind of a wondrous place is this Moon of ours?

7/20/69 NASA NO. AS11-37-5437

Figure 5.10-1. The page of Rene's book showing the allegedly fake Apollo photograph.

Rene wonders sarcastically what kind of a *"wondrous place is this Moon of ours"* if an engine shroud or thruster can *"cast a shadow over 79 miles* [127 km] *away"*.

As usual, we should ask ourselves why NASA would be so sloppy as to publish a photograph which showed a blatantly impossible phenomenon and thus would give away the fakery.

Actually, if we examine the original photograph (AS11-37-5437, Figure 5.10-2) instead of relying on Rene's very poor duplicate, it becomes clear that what Rene described as a shadow cast on the surface of the Moon isn't a shadow at all: it is nowhere as dark as the real shadows cast by the mountains and craters and actually has metallic reflections in its upper conical part.

In actual fact it's the silhouette of one of the thruster quads of the lunar module's upper stage, as can be seen in photo AS17-147-22527 (Figure 5.10-3), taken during Apollo 17.

In other words, this is not the distant shadow of a part of the spacecraft: *it's the part itself*, which is a few feet away from the observer. As often occurs, an alleged Moon mystery is spawned simply because the conspiracy theorist failed to perform basic research and inspect the original images.

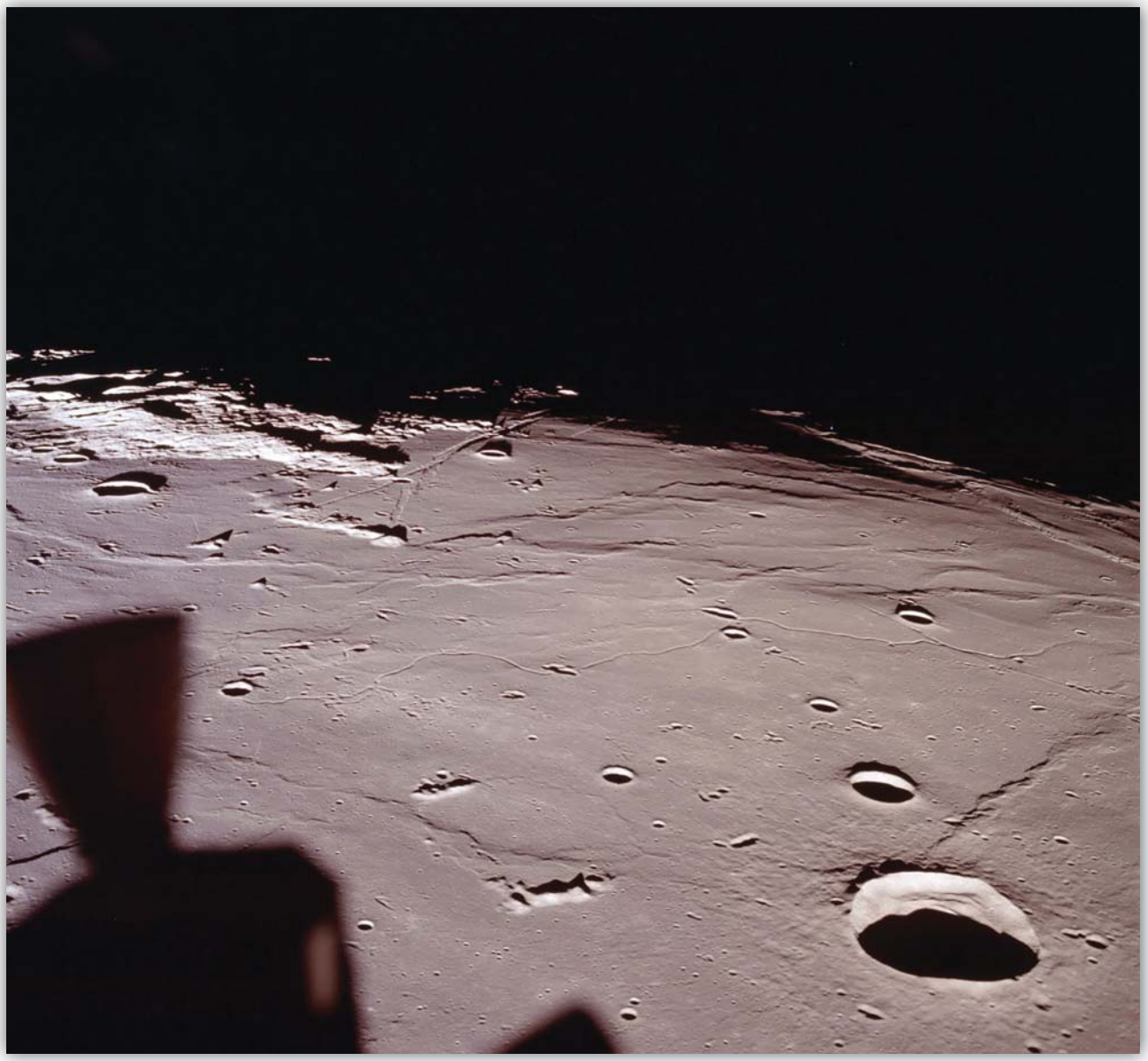


Figure 5.10-2. Photograph AS11-37-5437 (Apollo 11).

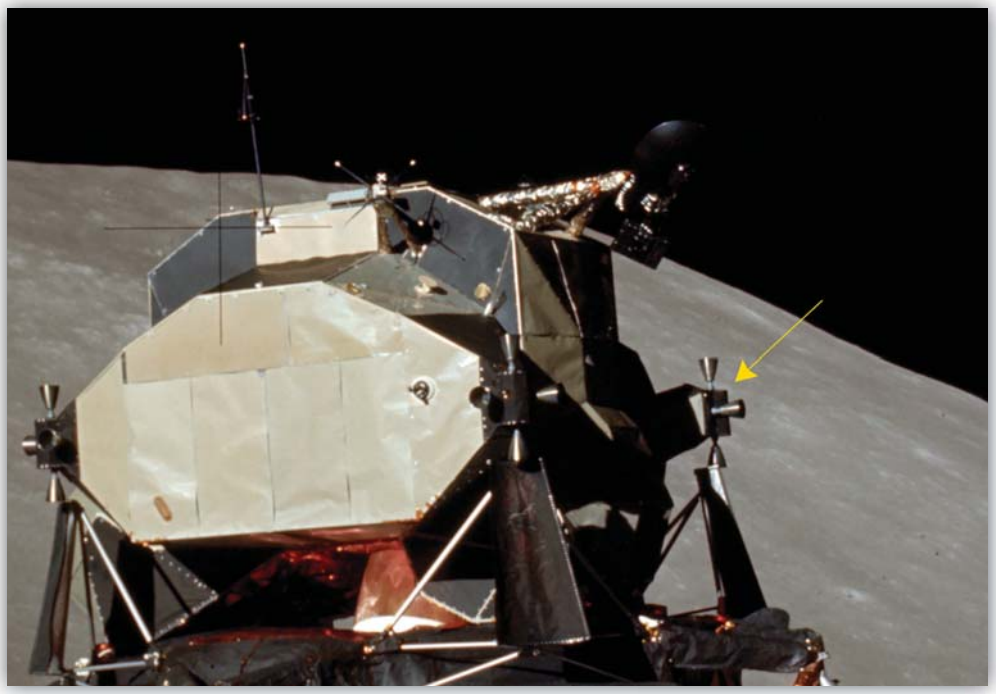


Figure 5.10-3. Detail of photo AS17-147-22527 (Apollo 17).

5.11 How can all the photographs be so perfect?

IN A NUTSHELL: *They're not. There are many bad pictures, but unsurprisingly NASA and the press usually prefer to show just the best ones.*

THE DETAILS: Mitch Pileggi, as host of the Fox TV show *Did We Land on the Moon?*, asks dramatically: *"If the cameras were so difficult to manipulate, how were thousands of photos taken with crystal clarity, precise framing?"* Then Bill Kaysing piles on the disbelief: *"The pictures that we see, that allegedly were taken on the Moon, are absolutely perfect!"*

It's a fairly reasonable question, considering that nobody had ever taken photographs on the Moon before, the



Figure 5.11-1. Photograph AS12-47-7009 (Apollo 12). A spacesuit helmet is recognizable in the bottom left corner of this probably unintentional shutter release.

cameras had fully manual exposure and focus, didn't have a viewfinder to aim them precisely and in any case could not be placed in front of an astronaut's eye to point them because of the spacesuit helmet.

The answer is that it's not true that all the Apollo photographs offer *"crystal clarity, precise framing"*: NASA, and consequently the press, simply published the ones that turned out well; the others were disregarded, as is standard practice in any photo report. Indeed, if we examine the full set of Moon pictures, we find dozens of underexposed, overexposed, blurred, out-of-focus, fogged and badly framed photographs, which are hardly ever shown precisely because they're so bad.

Here are a few examples (Figures 5.11-1 to 5.11-9):

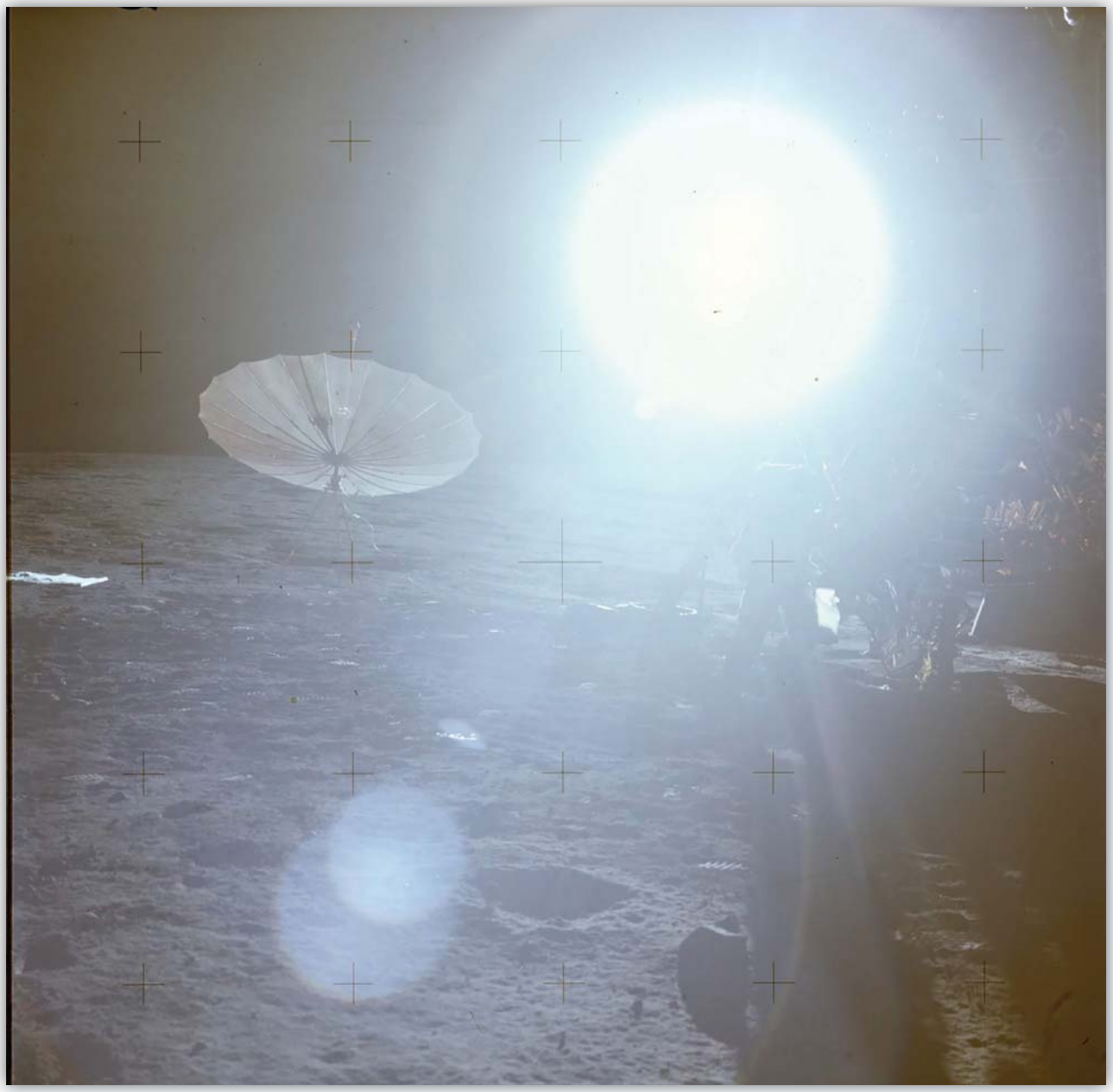


Figure 5.11-2. Photo AS12-47-6951 (Apollo 12). TV antenna and LM. An astronaut is barely visible.



Figure 5.11-3. Photo AS14-67-9382 (Apollo 14). One of the experiments on the lunar surface.



Figure 5.11-4. Photo AS17-133-20194 (Apollo 17). TV antenna and camera of the LRV.



Figure 5.11-5. Photo AS17-133-20246 (Apollo 17). Part of an astronaut is somewhat visible.



Figure 5.11-6. Photo AS17-133-20257 (Apollo 17). Blurred astronaut shadow.

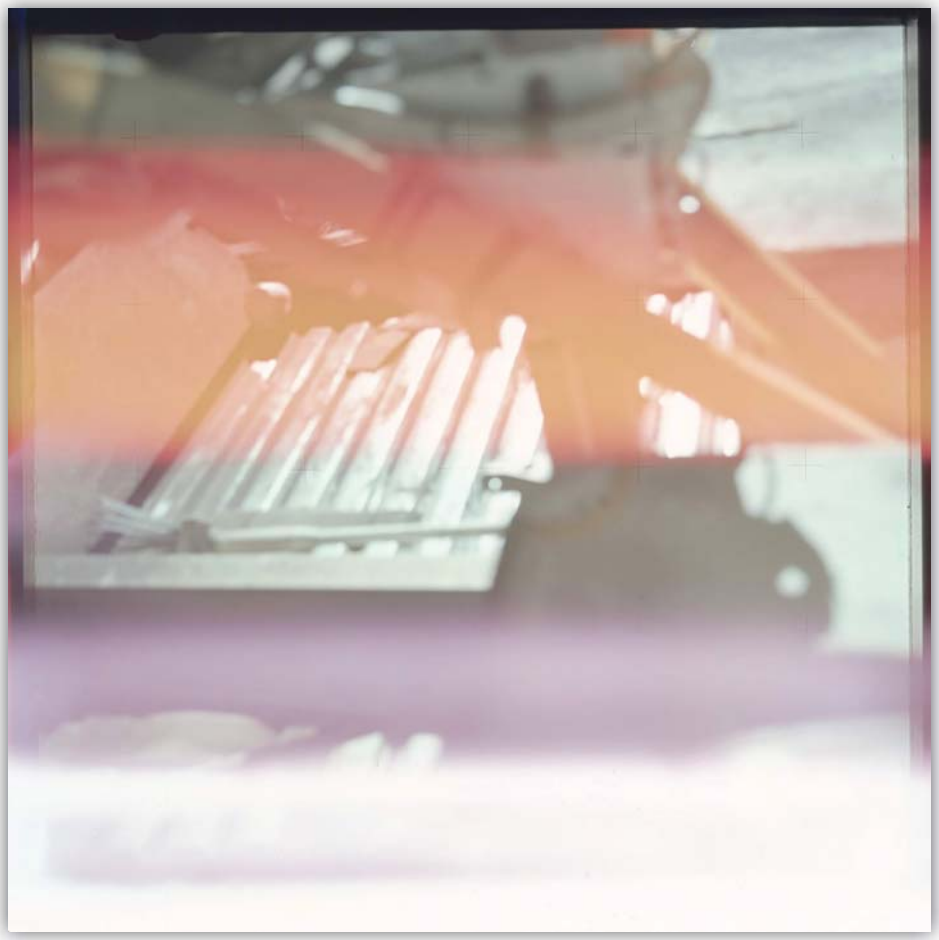


Figure 5.11-7. Photo AS17-145-22133 (Apollo 17). Detail of the LRV.



Figure 5.11-8. Photo AS17-145-22192 (Apollo 17).



Figure 5.11-9. Photo AS17-145-22226 (Apollo 17). Harrison Schmitt is barely discernible.

The complete sets of the Apollo photographs can be examined in very high resolution for example at the Lunar and Planetary Institute website or at Asu.edu and include many more examples of photographic mishaps.



Figure 5.11-10. Detail of the top portion of AS11-40-5903.

Even Neil Armstrong's world-famous portrait of Buzz Aldrin was almost a fiasco: careful inspection of the original shot (Figure 5.11-10) reveals that Armstrong almost cropped Aldrin's head (indeed, Aldrin's radio antenna is missing and the top of his backpack is out of the frame) and tilted the camera so much that a piece of fake sky is often added to this photograph in order to straighten it and make it look better.

So much for "*absolutely perfect*". When photographs could be disseminated only through the press, nobody wasted space and money by publishing the bad shots. That's why many people got the impression of absolute perfection. Today, however, the complete photographic record can be shared at no cost on the Internet and therefore all the images are now available for viewing.

Some of these photographic blunders are heartbreaking from a historical point of view. For example, consider NASA photograph AS11-40-5894 (Figure 5.11-11), taken during the Apollo 11 mission and shown below. It's a greatly underexposed picture of the LM. In the bottom left corner there's a barely recognizable silhouette of an astronaut. Analysis of the mission timeline allows to identify him: had it been exposed correctly, *it would be the only frontal portrait of Neil Armstrong on the Moon*.

Digital processing allows to recover some of the lost detail, as shown in the inset below, suggesting that Armstrong's gold reflective visor was raised and therefore his face would have been visible. This photo would be a wonderful portrait of the first human being to set foot on the Moon.

Anyone who wishes to try to recover this image can use the original film scan in TIFF format (189 MB) available on Asu.edu.

Despite these mistakes, the astronauts managed to bring back a good number of correct shots. How could they achieve this result on the first attempt? First of all, theirs were not the first photographs taken on the lunar surface: automatic probes had already sent back pictures of their landing sites. Therefore the lighting conditions of the Moon were known in advance and correct exposure settings were computed before leaving Earth. On the Moon, moreover, there were no clouds or haze that could alter the lighting.

The astronauts had also been trained for photography and were accustomed to composing their pictures simply by sighting along the camera's longitudinal axis, without using a viewfinder. Their cameras almost always had wide-angle lenses that had a broad viewing field and therefore didn't require very precise aiming.

The bright daylight also reduced focus problems by allowing to close the diaphragm of the camera, producing a great *depth of field* (range of distances that are in focus), which reduced the need for exact focusing of every photograph.



Figure 5.11-11. AS11-40-5894, an underexposed photograph of the Lunar Module on the Moon.



Figure 5.11-12. Digitally processed detail of photograph AS11-40-5894 (Apollo 11), showing Neil Armstrong more clearly. Credit: Andy Saunders, 2019.

5.12 How come there are photos of the landing site without the Lunar Module?

IN A NUTSHELL: *Because that's not the landing site; it's a different location nearly a mile away. The hills in the background look identical not because they're shot from the same location, but because they're actually distant mountains, which don't change appearance if the viewpoint moves by a mile or so, just like on Earth.*

THE DETAILS: Some Moon hoax theorists point out that there are pairs of Apollo photographs showing the landing site with and without the Lunar Module. They claim it's the same location because the hills in the background are absolutely identical in both pictures.

According to Fox TV's *Did We Land on the Moon?*, this is *"seemingly impossible, since the LM never moved and its base remained even after the mission."* And obviously there was nobody available to take photographs at the landing site before the LM landed, so there was no way to have a photo of the landing site without the LM. The show illustrates this argument with the pictures shown in Figure 5.12-1, which are also mentioned by Aulis.com and by French conspiracy theorist Philippe Lheureux.

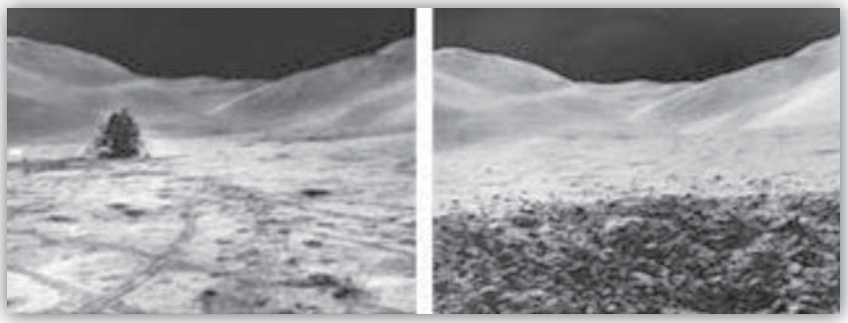


Figure 5.12-1. Two photographs with identical backdrops, shown in Fox TV's Did We Land on the Moon? *(2001).*

Hoax proponents often claim that this is evidence of fakery: they argue that the backgrounds were clumsily recycled to simulate different locations.

One might wonder why the alleged perpetrators of one of history's greatest and most important conspiracies would be so dumb as to reuse a movie backdrop and hope to get away with it, but never mind: a little research reveals the technical fallacy in the hoax theorists' argument.

The two photographs shown in Figure 5.12-1 come from the Apollo 15 mission: they're cropped versions of photos AS15-82-11057 (left, Figure 5.12-2) and AS15-82-11082 (right, Figure 5.12-3).

NASA's description of photos 11057 and 11082 reports that they were taken looking southwest and that the Apennine Mountains are on the left while the Hadley Delta mountain is on the right. Hadley Delta is 3500 meters (11,484 feet) high.



Figure 5.12-2. Photo AS15-82-11057.



Figure 5.12-3. Photo AS15-82-11082.

The mission records and the Apollo 15 *Surface Operations Overview* of the Lunar and Planetary Institute report that the first photograph was taken from a point named *Station 8*, approximately 125 meters (400 feet) northwest of the lunar module, while the second one was taken from another location, known as *Station 9*, 1400 meters (4600 feet) west of the LM and visible in the traverse map (Figure 5.12-5).

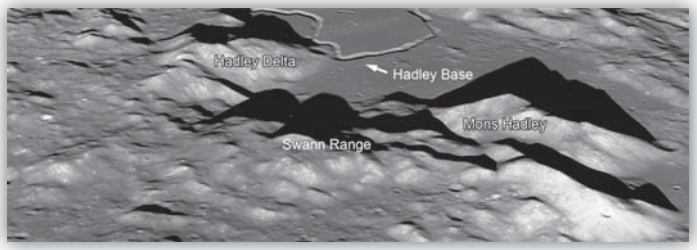


Figure 5.12-4. The Apollo 15 landing area photographed by the LRO probe (photo NAC M1123519889). Hadley Base is the exact landing site where the descent stage of the LM still stands today. Hadley Delta is the mountain located on the right in the photos in dispute, which were taken from the right looking left in the LRO photo. Credit: NASA/GSFC/ Arizona State University.

In other words, the lunar module is not in the second picture simply because the photograph was taken about a mile away from the spacecraft, not at the landing site.

So why is the background identical? Because what appear to be nearby gentle hills are actually massive and distant mountains that rise to more than 4500 meters (14,800 feet), such as Mons Hadley, which is 4600 meters (15,100 feet) high and can be seen on the right in Figure 5.12-4.

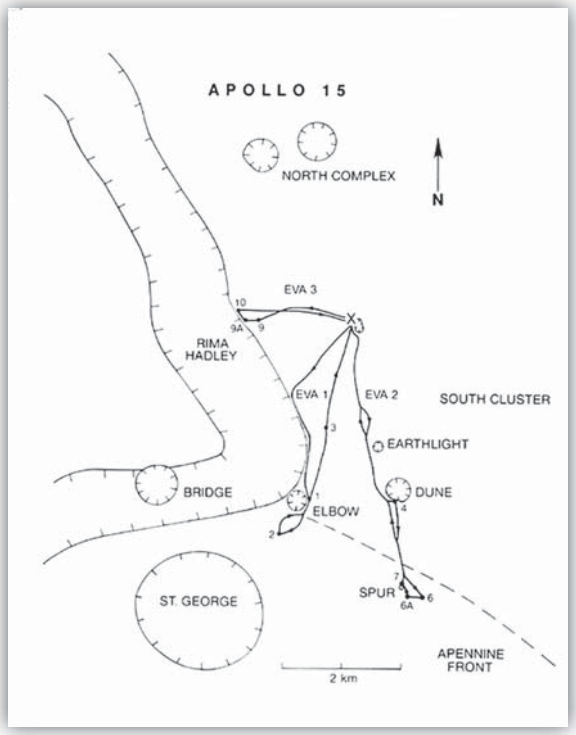


Figure 5.12-5. Detail of the Apollo 15 Traverse Map. Station 8 is not visible because it lies too close to the LM (indicated by X). The background of the photos in dispute is in the lower portion of this map.

We can determine the distance of this background by using a high-altitude photograph of the area, for example AS15-M-0414, taken from the Apollo 15 command module while it was orbiting the Moon, and superimposing on it the NASA traverse map of this mission (Figure 5.12-6). Using the scale reference of this map, it turns out that the foot of the nearest mountains, the ones on the right in the disputed photos, is about 3.5 kilometers (2.2 miles) from the spot where the photos were taken, while the mountains at the center are 14 kilometers (8.7 miles) and the ones on the left are about 21 kilometers (13 miles) away.

These distant mountains are misinterpreted as hills not only because of the lack of research by conspiracy theorists but also because on the Moon there's no air and therefore there is no telltale haze and there are no familiar size references, such as trees, roads or houses. Moreover, the horizon is a lot closer than on Earth: as mentioned previously, on level ground it is only 2.4 kilometers (1.5 miles) from the viewer.

All this makes it hard to realize that these are tall mountains rising from 5 to 26 kilometers (3.1 to 16.1 miles) from the landing spot and viewed from different locations. That's why

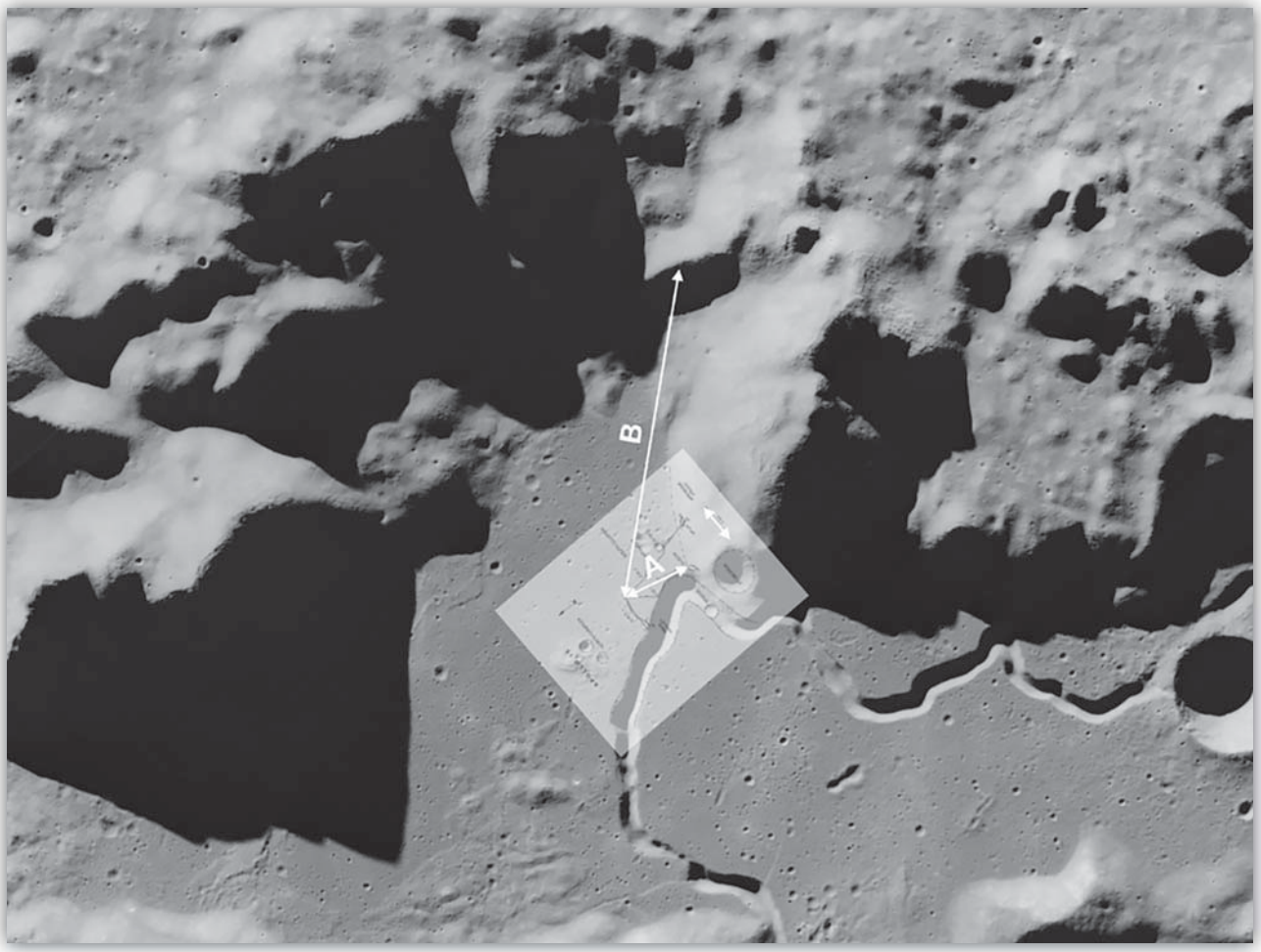


Figure 5.12-6. Detail of photo AS15-M-0414, aligned with the Apollo 15 traverse map. A = 3.5 km (2.2 miles); B = 14 km (8.7 miles). Credit: NASA/JSC/Arizona State University.

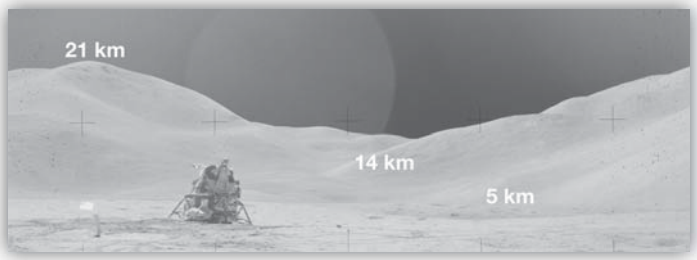


Figure 5.12-7. Detail of photo AS15-82-11057, annotated with the distances of its features: 21 km = 13 miles; 14 km = 8.7 miles; 5 km = 3.1 miles. The region labeled A in Figure 5.12-6 is not in the frame. The mountains at the center are even farther away (approximately 26 km, 16.1 miles).

this distant background seems to be unchanged while the foreground is completely different.

Suppose you photographed a tall mountain from a village located about 15 kilometers (9 miles) away, and then you moved about a mile to take another photo of the same mountain. You would not be surprised to find that the village houses in the foreground have changed completely but the mountain looks essentially the same. This is exactly what is going on in the Apollo photos questioned by conspiracy theorists: they were taken in two different places and show distant objects that remain essentially unchanged while closer ones change completely.

The claim that the background is a studio backdrop also doesn't stand up to scrutiny if the original photos are compared in detail. It turns out that the shape of these



Figure 5.12-8. Detail of photo AS15-82-11057.



Figure 5.12-9. Detail of photo AS15-82-11082.



Figure 5.12-10. Stereo pair for 3D viewer or parallel-eye viewing of photos AS15-82-11057 and 11082.

distant mountains actually changes, albeit very slightly, because of the change of viewpoint. This means that the mountains are three-dimensional objects, so much that their perspective changes.

This comparison is easier if you look at the central portions of the two Apollo 15 photographs (Figures 5.12-8 and -9) to find the differences in the contour of the maintains. In other words, the alleged backdrops are not identical at all as conspiracy theorists instead claim.

These differences can be used to create a stereo pair that reveals the three-dimensional depth of the allegedly flat backdrop (Figure 5.12-10).

Other cases of alleged recycled backdrops are discussed in *A Debunking of Jack White's Apollo Photo Analysis* (2012) on Robert Braeunig's *Rocket and Space Technology* website.

5.13 Why do the visors show reflections of studio lights?

IN A NUTSHELL: *They're not studio lights. They're reflections of sunlight on the scratches and smudges of the visors. This is made clear by looking at the high-resolution scans of the photographs. Similar reflections are seen in Shuttle and International Space Station images.*



Figure 5.13-1. An example of the alleged "studio lights", taken from Gernot Geise's appearance on Italian national TV show La Storia siamo noi *(RAI, 2006).*

THE DETAILS: Some Apollo photos show an unusual row of bright dots on the astronauts' helmet visors. Hoax theorists such as German author Gernot Geise have claimed that these

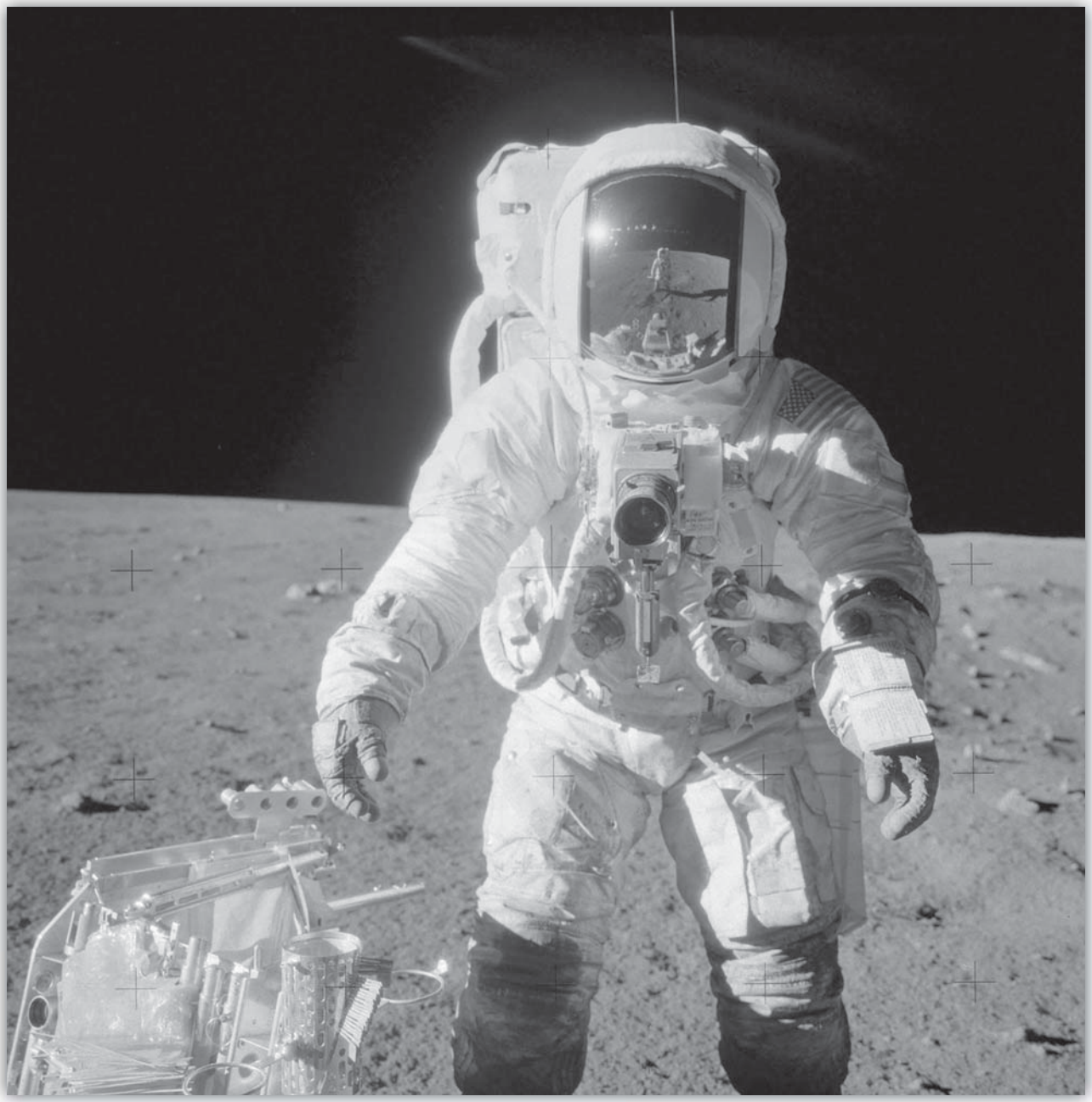


Figure 5.13-2. Alan Bean in photo AS12-49-7281 (Apollo 12).



Figure 5.13-3. An enlargement of the "studio lights" from a high-resolution scan of the original photograph AS12-49-7281.

are reflections from the rows of studio lights or from the windows of the control rooms used on the movie set where the Moon landing footage was faked.

As usual, conspiracy theorists fail to provide exact details and sources. It takes patient research to find out that the allegedly fake photo is a detail of an Apollo 12 picture, AS12-49-7281, taken by Charles "Pete" Conrad during the second moonwalk of that mission (Figure 5.13-2). The astronaut in the picture is Alan Bean; Conrad's reflection can be seen in his visor.

If you examine a high-resolution scan of the original photograph, it turns out that the alleged studio lights or windows are neither shaped nor arranged like studio lights or windows. The low-quality version shown by hoax proponents makes them appear to be evenly spaced circular dots, but in actual fact their shape and spacing are very irregular (Figure 5.13-3).



Figure 5.13-4. Sunlight reflecting off an Apollo suit visor produces a linear streak during training on Earth. Frame taken from the documentary When We Left Earth*.*

The explanation of this apparent anomaly is now quite obvious: these are reflections of sunlight on some of the scratches and smudges of the visor.

These blemishes were produced mainly by the astronaut's dusty gloves when they bumped against the reflective visor to lift or lower it or to move their sliding lateral eyeshades, which can be seen pulled down in AS12-49-7281 to the sides of the visor. Lunar dust is highly abrasive because it is not smoothed by wind or water as occurs on Earth: it acts like a sort of natural sandpaper. Apollo mission reports often mention scratches and clogging caused by moondust.



Figure 5.13-5. Italian astronaut Luca Parmitano's scratched visor in a self-portrait taken during work outside the International Space Station in July 2013. NASA photo ISS036-E-016853.

Similar lines of reflected sunlight can also be seen to the side of the Sun's main reflection in pictures of the Apollo spacesuits taken on Earth during training, such as the one shown in Figure 5.13-4. It seems unlikely that there was any need to place a row of spotlights in the sky for this picture.

More recent photographs taken during spacewalks from the US Space Shuttle and the

International Space Station, too, show scratched visors: scuffing occurs even in the relatively pristine environment of space. An example is the photo shown in Figure 5.13-5, taken during Italian astronaut Luca Parmitano's ISS spacewalk in July 2013.

Another example is provided by Shuttle mission STS-118, in August 2007 (photo ISS015-E-22561). In particular, in the top left region there is a triangular smudge that closely resembles the alleged "studio lights" claimed by conspiracy theorists (Figure 5-13-6).



Figure 5.13-6. Scratches and scuffs on the visor of astronaut Clay Anderson as he works outside the International Space Station (2007). Photo ISS015-E-22561.

One should also take into account the fact that the Apollo helmet used for moonwalks and spacewalks consisted of an inner bubble helmet, a transparent central visor and an outer gold-coated visor. Light striking the outer visor would be reflected back and forth between the three layers, easily forming repeating patterns of light spots.

5.14 How can the camera crosshairs be behind objects?

IN A NUTSHELL: *The crosshairs aren't behind them; they're washed out, as occurs often for any thin object photographed against an overexposed bright background, especially after repeated analog duplications of a photo. The apparently covered crosshairs are often visible in the original pictures.*



Figure 5.14-1. Crosshairs on a glass plate inside a Hasselblad camera. The film magazine has been removed for clarity.



Figure 5.14-2. Suspicious crosshairs according to David Percy.

THE DETAILS: The Hasselblad cameras used for most Moon photographs were fitted with a glass plate, or *reseau plate*, which was in direct contact with the film when a photograph was taken. Crosshairs, known as *fiducials* or *reseau marks*, were etched on this glass plate. This superimposed the crosshairs directly on the original shot.

These crosshairs were arranged in a 5 x 5 grid. The central crosshair was larger to distinguish it from the others and indicate the center of the original photograph. Each arm of the normal-size crosshairs was 1 millimeter (0.039 inches) long and 0.02 millimeters (0.00078 inches) wide. The crosshairs were used to reveal any warping during the developing, printing and duplication processes and for distance measurements.

Moon hoax theorists point to the curious fact that in some of the Apollo photographs these crosshairs are *behind* the objects being photographed, as can be seen for example in Figure 5.14-2.

According to David Percy in the TV show *Did We Land on the Moon?* (2001), *"this situation is impossible and has to be the result of technical manipulation and doctoring of the image"*.

But actually there's a very simple explanation for this allegedly *"impossible"* situation. The main clue is in the pictures chosen by the Fox show: every object that appears to cover the crosshairs is white and strongly lit by sunlight.

It turns out that if you take a photograph of a dark, thin object against a bright, overexposed background, the thin object tends to disappear: it gets washed out by the surrounding glare. This effect is well-known to

photographers as *blow-out*, *wash-out* or *bleeding*, and can be seen for example in Figure 5.14-3, where the black thread that crosses the picture becomes invisible when it lies in front of the brightly sunlit model astronaut.



Figure 5.14-3. A black thread is clearly visible against a correctly exposed background but vanishes when it lies in front of the overexposed model astronaut. Credit: PA.

The same effect occurs during analog duplication of photographs: fine detail is washed out and gradually lost.

If you examine high-resolution, direct scans of all of the allegedly doctored photographs, you find exactly the same effect: the apparently missing portion of the crosshairs is always on a very bright, overexposed background, and it turns out that often it's not missing at all but simply very faint.

The Fox TV show and other sources that discuss these apparent anomalies show low-quality copies of the pictures instead of high-quality scans: another recurring trick used by conspiracy theorists.

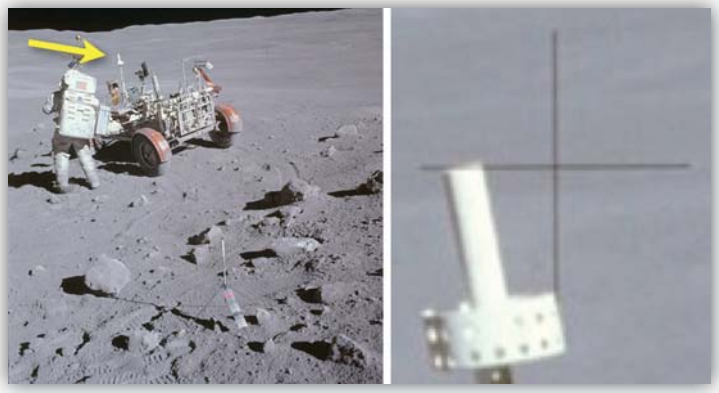


Figure 5.14-4. Photo AS16-107-17446 and detail of the same picture.

A high-quality scan of the first photograph in dispute (Apollo 16 photo AS16-107-17446) is shown in Figure 5.14-4. The detail is indicated by the arrow and is shown magnified on the right, revealing that the "missing" crosshair is actually quite present.

Figure 5.14-5 is instead a better scan of Apollo 11 photograph AS11-40-5931, which is the second allegedly doctored picture. The arrow points to the region where the supposedly missing crosshair is located. It is in actual fact quite visible, although somewhat washed out where it lies in front of a white background.

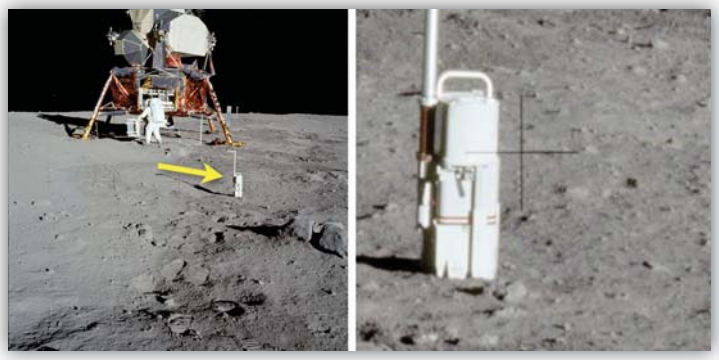


Figure 5.14-5. Photo AS11-40-5931 and detail of the same picture.



Figure 5.14-6. A detail of photo AS11-40-5931 from a late 1969 Kodak print (by kind permission of Adriano Carrata).

The washed-out crosshair is also visible in the scan of a late 1969 Kodak print shown in Figure 5-14.6. The dating of this print refutes the theory that the apparently wrong crosshairs were fixed years after the Apollo missions.

In other words, there's nothing strange about the crosshairs in the lunar photographs. On the contrary, the*y* behave exactly as required by the laws of optics that affect photography and therefore they are not evidence of doctoring.

5.15 How come there's a letter C on a rock?

IN A NUTSHELL: *It's not a letter, it's a hair that got into one of the many duplication processes to which the Apollo photographs were subjected for distribution. It's not on the original film.*

THE DETAILS: In a photograph from the Apollo 16 mission record there's a clearly outlined letter C on a rock and another letter C on the ground next to it. According to French hoax theorist Philippe Lheureux, this is *"exactly like with some cinema props."* Ralph Rene concurs: *"The large rock in the left foreground is clearly marked with a big capital "C". The bottom right corner has a crease similar to that caused by wetting a folded newspaper. This makes it a showbiz "flap" rock, which the people who work in Hollywood studios throw at visitors. They used to be made from wet newspaper and paste and showed similar flaps. Stage rocks are usually placed by stage hands over similarly lettered markers positioned by the set designer. Did NASA really carry fake boulders and stage hands onto the Moon?"*[1].

1 *Moon shots 'faked',* BBC News, 21 June 2001; *NASA Mooned America!*, Ralph Rene, page 6.

The photograph is AS16-107-17446 (the same one that has the allegedly missing crosshairs) and shows astronaut Charlie Duke at the Station 4 site of Stone Mountain. The alleged letter C is on a rock toward the bottom left corner of the picture and can be seen in the detail shown in Figure 5.15-1, which is excerpted from pro-conspiracy site Aulis.com. Another apparent letter C is on the ground close to the rock.

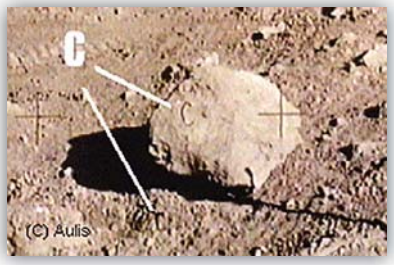


Figure 5.15-1. The alleged letters C on a rock and on the lunar surface. Image source: Aulis.com.

This alleged piece of evidence is so absurd that it begs the question of how anyone can present it seriously as proof of fakery without realizing that it makes no sense. The official publication of a photograph showing two letters C that shouldn't be there, revealing the top-secret deception that was vital for the destiny and reputation of the United States, would entail a truly unbelievable chain of errors.

- First, the set decorator would have to dress the set without realizing that not one, but *two* reference letters are visible to the cameras.
- Then the photographer would have to take the picture without noticing the two letters.
- Then all the people who developed, selected and published the photographs would have to fail to notice the telltale mistake.

The idea that the rocks would be individually labeled with a *single letter* to assist in their placement also strains credulity. A one-letter labeling system would allow for only twenty-six rocks, which on a set depicting a rock-littered lunar surface might be somewhat inadequate.

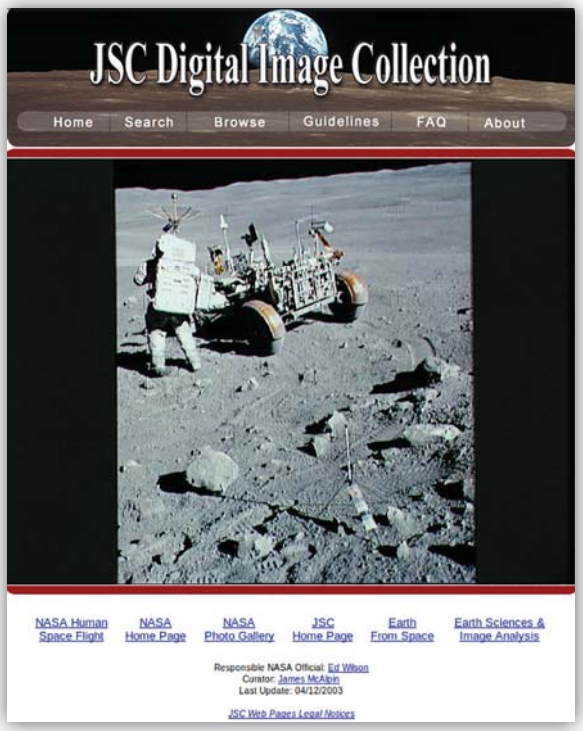


Figure 5.15-2. The photograph with the alleged letters C (bottom left) in the low-resolution Internet archive copy of the Johnson Space Center as it was in 2004 (Archive.org).

Moreover, if the letter C were actually drawn on a sloping face of a rough, irregular rock or on the uneven soil, it wouldn't have such a smooth shape when viewed from an angle as occurs in this photograph.

Yet despite all this, the fact remains that the letters are unquestionably present in the "official version" published by the NASA website of the Johnson Space Center, shown in Figure 5.15-2.

The answer to this conundrum, for once, was found by a conspiracy theorist, Steve Troy of Lunaranomalies.com, in 2001 (the original site no longer exists, but Archive.org has preserved a copy made in 2008). His fellow theorists, however, seem to have ignored his research and continue to peddle this alleged evidence.

In 2001 Troy ordered from various NASA agencies film duplicates of this photograph and analyzed them in search of the letter. It wasn't there. So he contacted the same agencies to inquire why the letter was instead present in one of the "official" NASA websites.



Figure 5.15-3. The "letter" is revealed to be simply a hair.

One of these agencies, Houston's Lunar and Planetary Institute (LPI), found that one of their reference *prints*, but not their *films* (duplicates of the Apollo originals), had the alleged letter. LPI supplied Troy with a scan of that print at the highest possible resolution. It turned out that the letter was actually a tiny hair.

This high-resolution image clearly shown that the alleged letter is not a pencil or felt pen mark: it's a curled-up filament-like object. Coincidentally, the alleged letter has one of the shapes that can be most easily assumed by a hair: it's a C, not a K, F, M or A, for example.

The Johnson Space Center explained to Steve Troy that one of these imperfect prints had been scanned in the late 1980s or early 1990s and had remained on the website since then. More recent, higher-quality scans taken directly from the original film are available online and don't show the hair.

These scans also reveal that the other alleged letter, the one on the ground, is just a shadow that looks vaguely like a letter C, generated by a tiny bump in the lunar surface, as shown in Figure 5.15-5.



Figure 5.15-4. Photo AS16-107-17446. Scan from the Project Apollo Archive (2015).

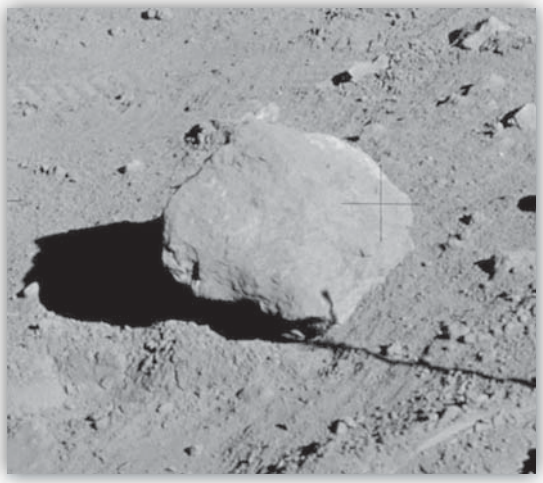


Figure 5.15-5. Detail of a more direct scan of the original photograph AS16-107-17446.

5.16 How come the backpack antenna appears and disappears?

IN A NUTSHELL: *It only "disappears" if you look at the low-resolution copies of the photographs. It doesn't in the high-quality scans, but it becomes fainter. This is because it was a flat antenna and therefore it became almost invisible when it was edge-on to the camera or to the Sun.*

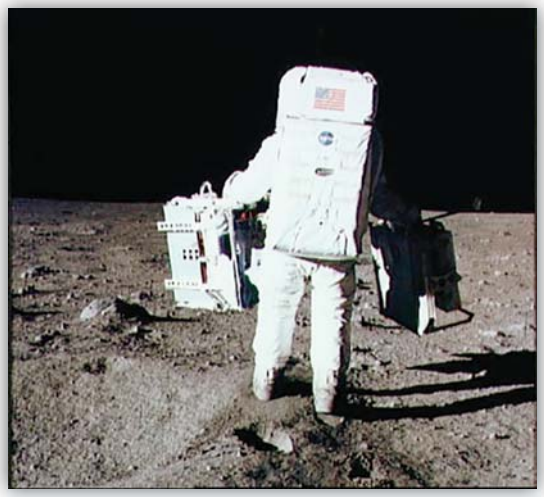


Figure 5.16-1. Detail of photo AS11-40-5942: where's the backpack antenna?

THE DETAILS: The PLSS radio antenna, located at the top of the astronauts' backpacks, seems to come and go in photographs taken moments apart. This is interpreted by some as evidence that the photographs were not taken in sequence and someone forgot to place the antenna consistently in the various photographs.

An example of the disappearing antenna is offered by photos AS11-40-5942 and AS11-40-5943 from the Apollo 11 mission, which show Buzz Aldrin as he carries the instruments to be left on the Moon. The numbering of these photographs implies that they were officially taken in sequence. Yet the antenna appears to be missing in the first one (Figure 5.16-1) and distinctly visible in the second one (Figure 5.16-2).

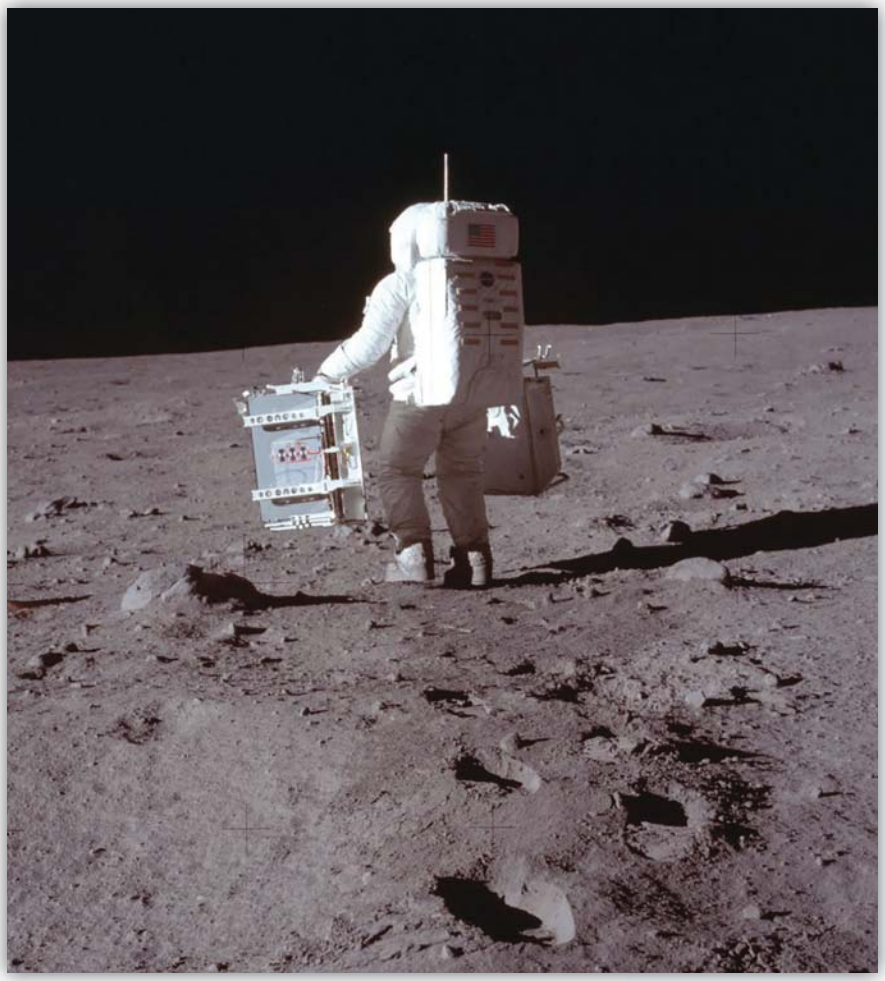


Figure 5.16-2. Detail of photo AS11-40-5943: the antenna is clearly visible.

Once again, this apparent inconsistency arises from one of the recurring mistakes of conspiracy theorists: using low-resolution copies instead of high-quality scans of the originals.

The first picture comes from the low-resolution online set of the Johnson Space Center and apparently shows no antenna, but inspection of the high-resolution version of the photograph

(Figures 5.16-3 and 5.16-4) reveals that the antenna is actually present, although it's very faint.

Why does the antenna look so different in the two pictures? The answer requires in-depth knowledge of Apollo equipment and therefore it's understandable that some conspiracy theorists and many doubters are misled by their preconceptions. It's less understandable that they accuse NASA of fakery without first checking in publicly available documents how these antennas were made.

The VHF aerials of the astronauts, used for radio communications, were not traditional rod-like parts, with a circular cross-section: they were slightly curved metal strips, stowed flat before and after use as shown in Figure 5.16-5.

Seen edge-on, i.e., when the astronaut is directly facing the camera or has his back to it, these flat VHF antennas are almost invisible against the black lunar sky. Seen from

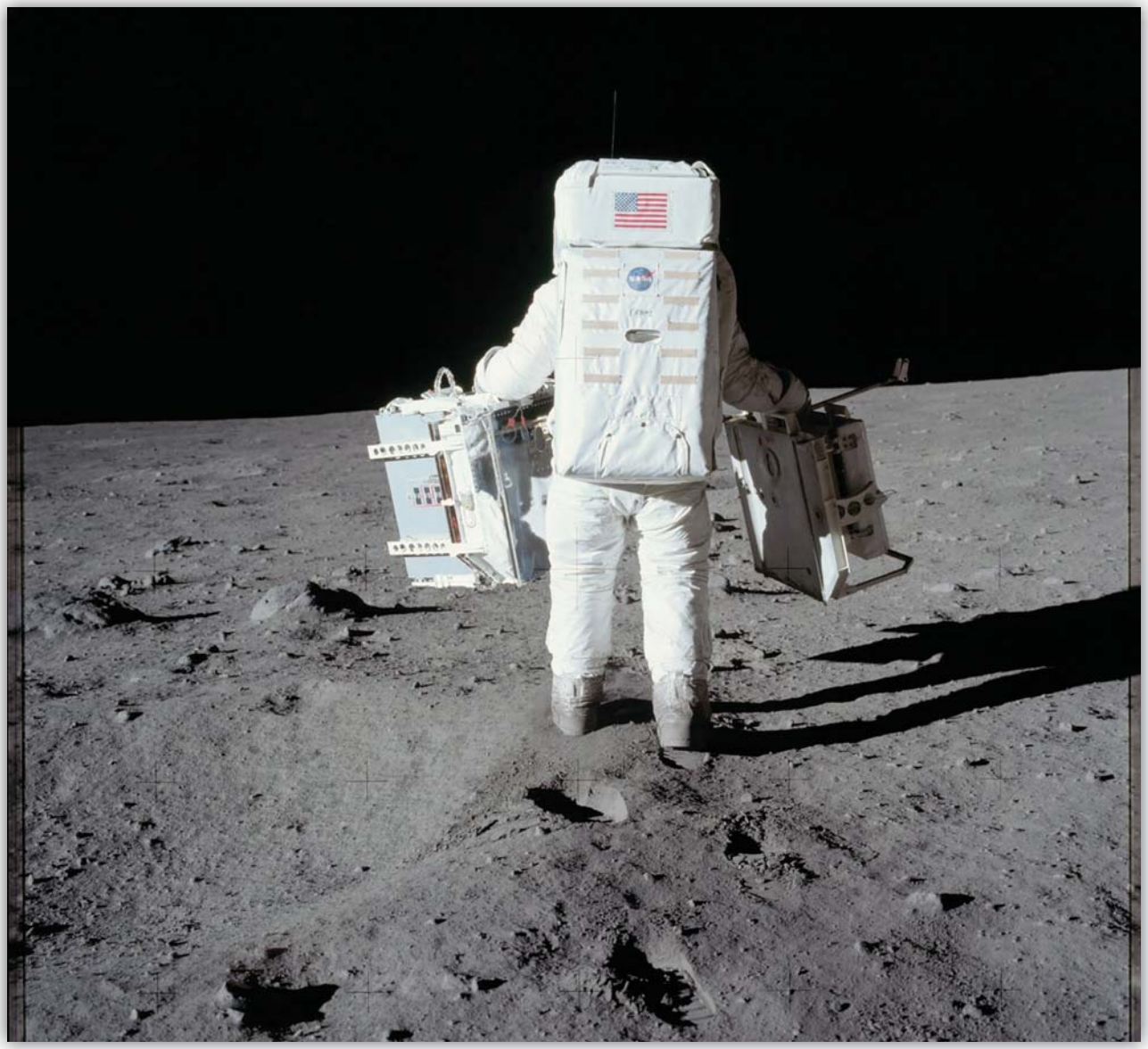


Figure 5.16-3. Photo AS11-40-5942 (high-resolution scan).



Figure 5.16-4. Detail of a high-resolution scan of photo AS11-40-5942.

the side, they become clearly visible by reflecting the sunlight from a much wider surface.

In the first picture (5942), Aldrin is seen squarely from the back and therefore the antenna is edge-on to the camera. In the second picture (5943), the astronaut is turned sideways and so his antenna is showing its flat side to the camera. That's why it's so much brighter.

In other pictures, such as AS11-40-5874 (the flag salute), the astronaut is seen from the side, but he's facing the sun and therefore the antenna is edge-on with respect to the light source, so only its front edge catches the light, making it hard to see except in the high-resolution scans.



Figure 5.16-5. Detail of the stowed VHF antenna of Charlie Duke's spacesuit (Apollo 16). Courtesy of K.C. Groneman and D.B. Eppler, NASA Johnson.



Figure 5.16-6. Detail of photo AS11-40-5874.

5.17 How come Aldrin looks like he's standing in a spotlight?

IN A NUTSHELL: *He's not. He's standing in a patch of the lunar surface where the lunar module's rocket exhaust swept away the dust, making the surface brighter. Also, the spotlight-like effect is exaggerated in low-quality copies of the photos and is less pronounced in direct scans of the originals. Other natural optical phenomena, such as the way the dust reflects light, can also cause brighter areas in photographs.*

THE DETAILS: Several Moon hoax theorists observe that in some photographs of the Apollo 11 landing, such as AS11-40-5903 (Buzz Aldrin's "tourist photo"), the ground around the astronaut is far brighter than the rest. As the distance from the astronaut increases, the ground becomes unusually darker. This effect, they claim, is the result of a studio spotlight.



Figure 5.17-1. Photo AS11-40-5903 as printed in the August 1989 issue of Italian photography magazine Fotografare*.*

This alleged evidence is often illustrated by copies of these photographs in which the contrast has been pushed, exaggerating the difference in brightness, as in the example shown in Figure 5.17-1, which is taken from *Fotografare*, an Italian photography magazine whose editor supported the claims of fakery. Moon hoax literature knows no language barrier.

The common-sense objection to this allegation is to ask why the organizers of the hypothetical fakery on behalf of the US government would make such a stupid lighting mistake. Couldn't they afford enough spotlights?

Another objection is that if Aldrin is standing in a studio spotlight, his shadow should be washed out in the spotlit patch and then be dark in the foreground, where the "spotlight" effect ceases, but it isn't.

Moreover, a spotlight would produce a second shadow of the astronaut, but there isn't one in the pictures.

There's another problem with this conspiracy theory: the original photographs don't show this spotlight effect. It only appears in the low-quality versions used by these theorists.

The simple explanation, in other words, is that the alleged "hotspot" or "spotlight" effect is only an artifact generated by poor duplication and by boosting contrast to extreme levels.

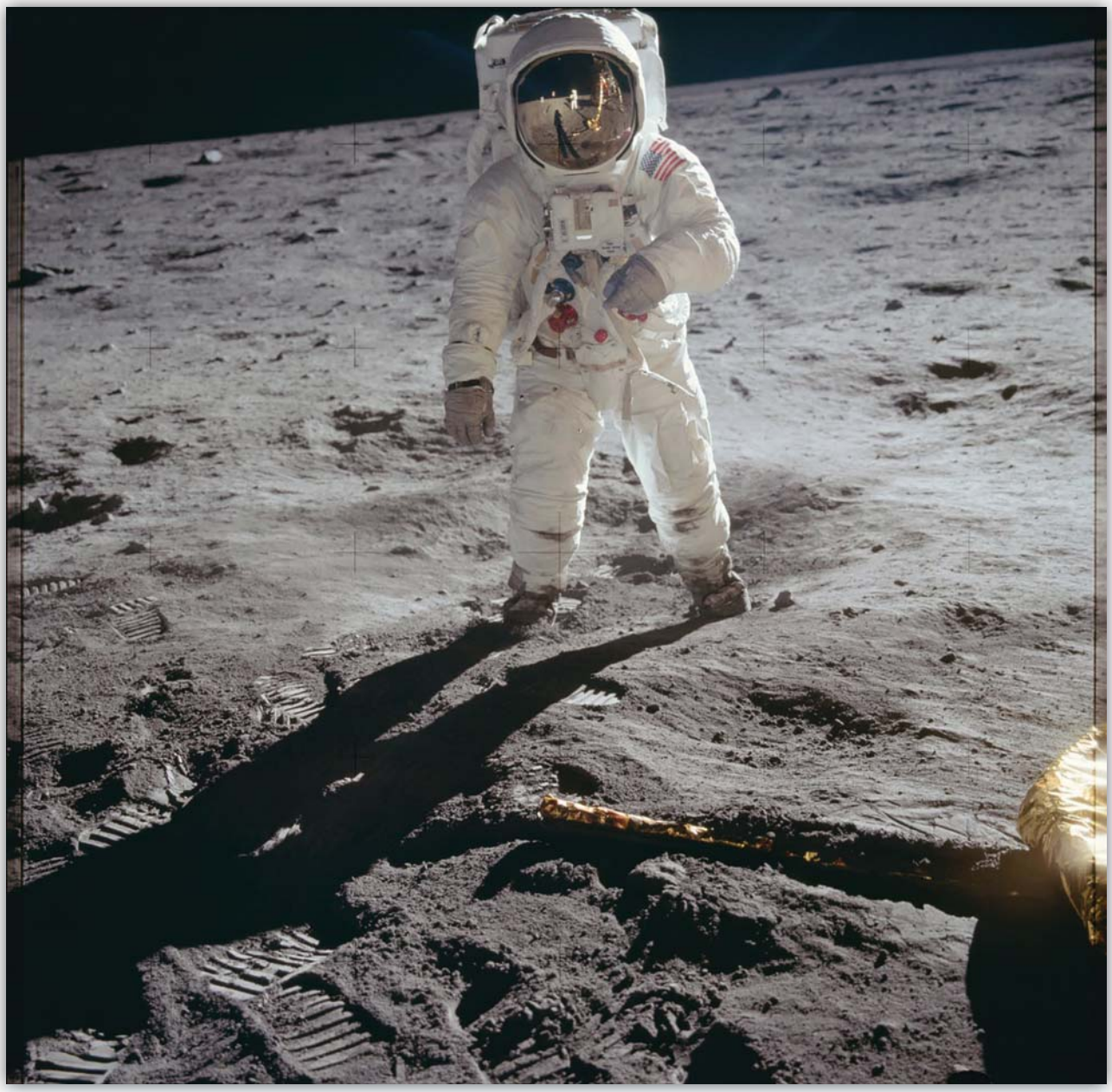


Figure 5.17-2. A direct scan of photo AS11-40-5903.

However, there is a *slight* difference in ground brightness even in the original scans. In Figure 5.17-2, the foreground is somewhat darker than the area where Aldrin is standing, and the terrain behind the astronaut is likewise darker. The slightly brighter area appears to be a roughly central band that sweeps diagonally from left to right.

If the difference in brightness of the ground can't be explained by lighting conditions, then perhaps the ground itself was brighter around Aldrin for some reason. Finding that reason requires a bit of detective work.

First of all we need to locate that part of the ground. In the uncropped version of AS11-40-5903, a leg of the lunar module is visible next to Aldrin. The direction of the shadows

allows to determine that it's the LM's right leg (as seen from the crew compartment). So the brighter ground is to the right of the lunar module's right leg (again as seen from the crew compartment).

This is confirmed by other photos of the same area, such as AS11-40-5902 (Figure 5.17-3), which shows the same band of brighter soil.

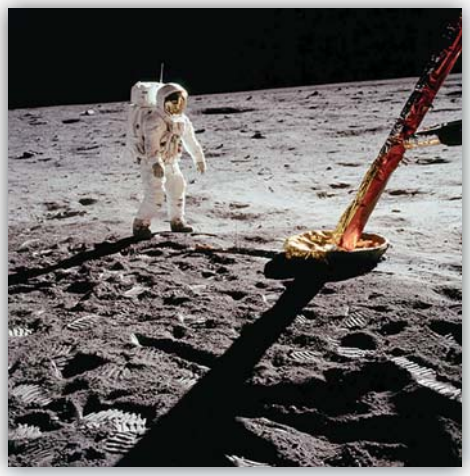


Figure 5.17-3. Photo AS11-40-5902 (Apollo 11).

Figures 5.17-4 and 5.17-5 show other photographs taken from the same location but with the camera pointing further to the left (AS11-40-5885 and AS11-40-5886). The same banding is visible.

These photos, too, exhibit the same "spotlit" effect despite the fact that there's no astronaut in the brighter patch (Neil Armstrong is in the picture in

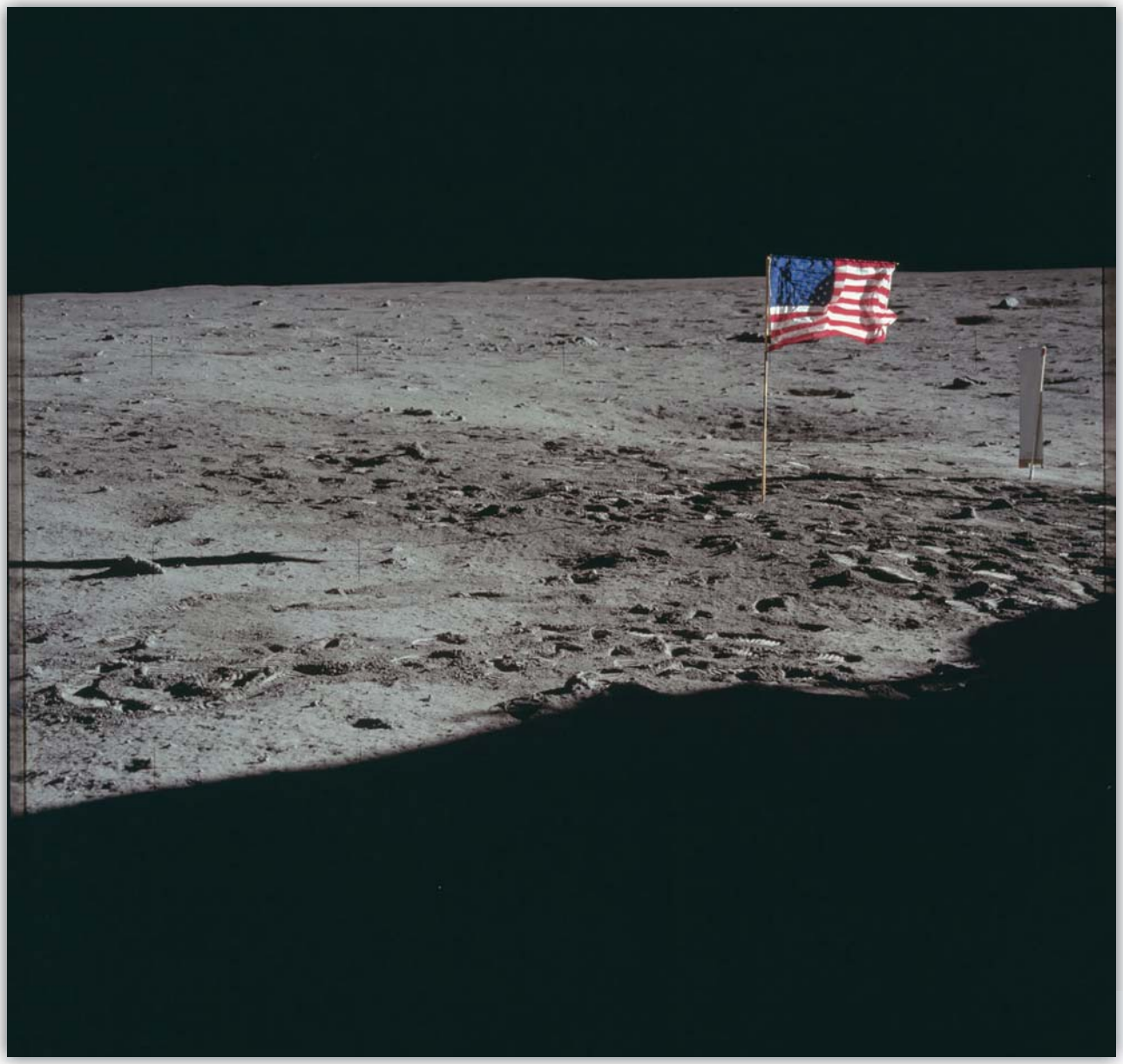


Figure 5.17-4. Photo AS11-40-5885. A streak of dark soil crosses the frame diagonally.

AS11-40-5886, but he's standing in the shadow of the LM). Why would the alleged fakers put a spotlight there when there's no astronaut to be spotlit?

More importantly, the wider view reveals that the brighter region is actually an elongated streak that crosses the picture diagonally from the upper left to the lower right, and that the LM's shadow is roughly at right angles to the streak.

The high-resolution scans of these photographs also suggest that the brighter patch is almost dust-free (astronaut bootprints are shallow or nonexistent in it), as if something had swept away the dust in that particular area and exposed a band of the underlying smoother, more reflective rock.

That *something* could be the LM's descent engine exhaust, if the spacecraft had moved sideways just before touchdown. It did. The radio communications logs and the 16 mm film



Figure 5.17-5. Photo AS11-40-5886 shows dark soil in the central band and brighter soil in the upper portion.

footage of the landing show that the LM drifted mostly sideways, first to the right (Aldrin: *"4 forward. 4 forward. Drifting to the right a little"*) and then to the left, seconds before landing, with negligible forward velocity.

This path is also supported by telemetry data, by the small pits to the sides of the LM footpads, and by the orientation of the contact probes that stick out of the ground.

The Apollo landing instructions required the astronauts to fly the LM with the sun behind them, so that they could use the LM shadow as an altitude reference. This is confirmed by the 16 mm footage. Therefore the general direction of approach in photos 5902 and 5903 is from the upper left: the LM's exhaust swept a band arranged roughly at right angles to its direction of approach.

In other words, the explanation that best fits all the available facts is not that a spotlight was secretly and clumsily used, but that Buzz Aldrin was standing in the band of lunar ground that had been swept by the LM's rocket exhaust,



Figure 5.17-6. Photo AS17-134-20435.

which had blown away the surface dust, exposing the brighter rock below.

In addition, the soil in the foreground has been churned up by the astronauts' steps and this reduces its reflectivity.

This is a good example of how it can be challenging, even for a very expert photographer, to explain the apparent anomalies that occur in some Moon photographs without knowing the technical details of the circumstances in which they were taken.

Center hotspots

In some Apollo photographs (Figures 5.17-6, -7, -8, -9 and -10), the lunar soil is more brightly lit in the central region of the image. This, too, might be interpreted as the effect of a clumsily setup spotlight.

Actually, this is an entirely natural phenomenon, which



Figure 5.17-7. Photo AS17-136-20684.



Figure 5.17-8.
Photo AS17-140-21359.



Figure 5.17-9.
Photo AS17-142-21798.



Figure 5.17-10. Photo AS17-147-22473.



Figure 5.17-11. The Yutu 2 rover, photographed by the Chang'e-4 probe on the far side of the Moon, 4 January 2019. Credit: CNSA/EPA. Color correction by David Rothery for the Planetary Society.

occurs also in photographs taken on the Moon by the Chinese Chang'e probes, as shown in Figure 5.17-11.

This effect occurs in Lunar dust, and in dust in general, when the Sun is directly behind the camera. The grains of dust at the center of the frame only show their sunlit sides to the camera, whereas the grains that lie off-center also show part of their shadow sides. The visibility of these small shadows reduces the overall brightness of the peripheral regions of the photo from the point of view of the camera. The effect is known as *zero*

phase, *opposition surge*, *shadow hiding* or *heiligenschein* and also occurs on other celestial bodies, including the Earth.[2]

A particularly good example of this phenomenon is provided by photographs of asteroid Ryugu taken by the Japanese probe Hayabusa 2 in 2019, which show the shadow of the probe on the asteroid, surrounded by a bright halo, as in Figure 5.17-12.

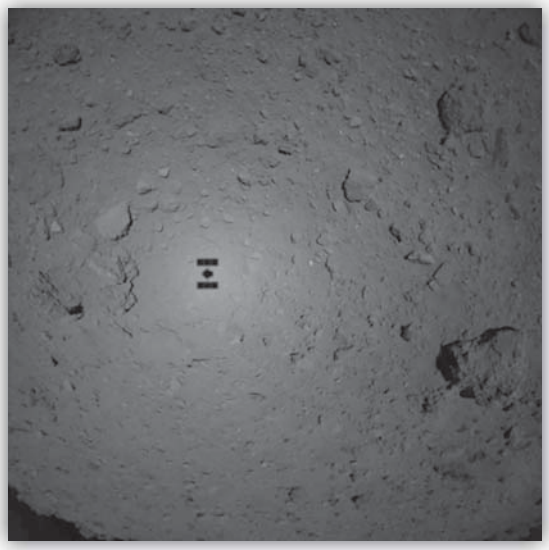


Figure 5.17-12. The shadow of the Hayabusa 2 probe on asteroid Ryugu. Credit: JAXA, 2019.

2 *Heiligenschein Throughout the Solar System*, by Brittney Cooper, Planetary.org (2018); *Analysis of Apollo 10 Photography and Visual Observations*, NASA SP-232 (1971); *The Moon's photometric function near zero phase angle from Apollo 8 photography*, Pohn, H. A., Radin, H. W., & Wildey, R. L., *Astrophysical Journal*, vol. 157, p. L193-L195 (1969); *Apollo Chronicles: Dark Shadows*, NASA (2006); *Hayabusa observes the "opposition surge" of Asteroid Itokawa*, Spaceref.com (2005).

5.18 Shouldn't backlit photos shot in a vacuum just show silhouettes?

IN A NUTSHELL: *No, they shouldn't. The shadow side of a backlit astronaut is lit by the light reflected off nearby objects. Reflection doesn't need an atmosphere and works fine in a vacuum. This is demonstrated by many other undisputed space photographs.*

THE DETAILS: Many supporters of Moon photo fakery theories have remarked that in some pictures the astronauts have the sun behind them and are therefore brightly backlit, yet they don't show up as dark silhouettes as normally happens in backlit situations. On the contrary, their shadow side is perfectly visible.

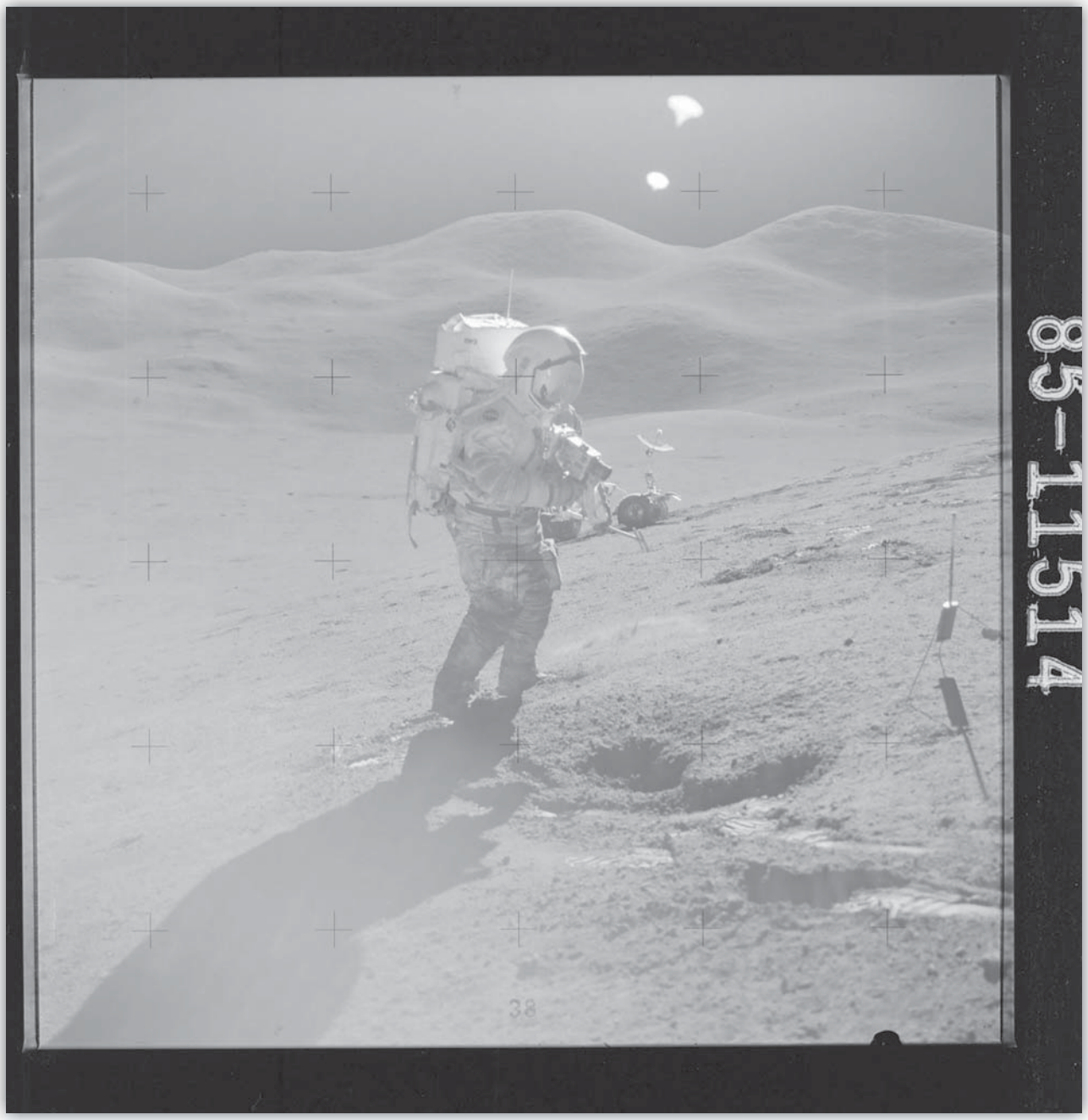


Figure 5.18-1. Photo AS15-85-11514 (Apollo 15).

An example of this phenomenon is Apollo 15 photograph AS15-85-11514 (Figure 5.18-1): the direction of astronaut David Scott's shadow indicates that the photographer, James Irwin, is facing the sun and therefore Scott's side facing the camera is in shadow, yet we can see it clearly. It is claimed that this is impossible in the vacuum of the Moon, because there's no atmosphere to diffuse the sunlight and therefore the shadow side of an astronaut should be pitch black. The same claim is applied to Aldrin's famous photo, AS11-40-5903 (Figure 5.18-2).

This argument is based on an incorrect premise. In actual fact, the laws of physics and optics say that the presence of an atmosphere has nothing to do with the possibility to take backlit photographs. The shadow side of a backlit object is not lit by *diffusion*, which is the scattering of light produced by the gas molecules, suspended dust and water droplets

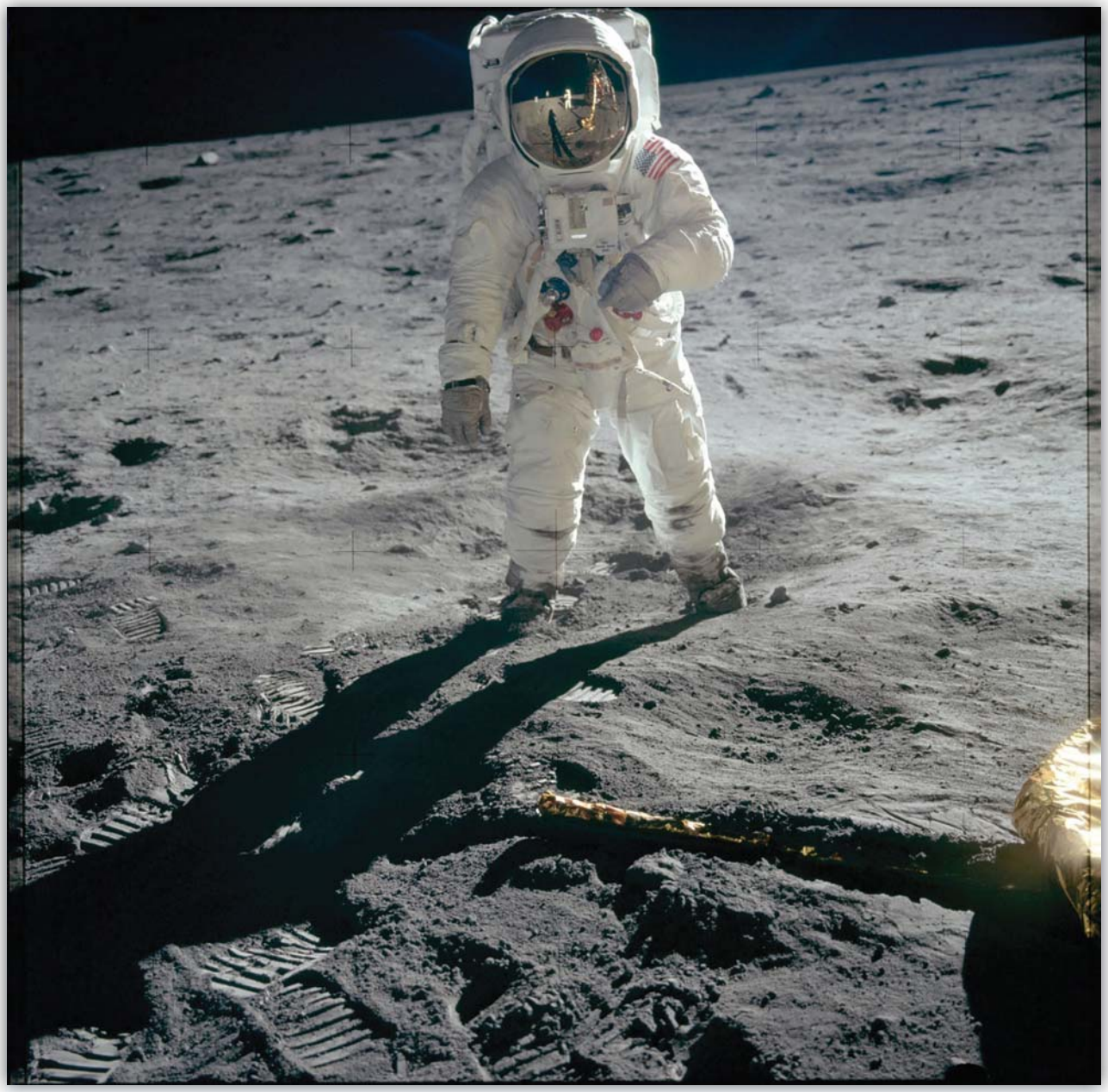


Figure 5.18-2. Aldrin on the Moon. Photo AS11-40-5903.



Figure 5.18-3. Reflection on a bright surface is often used to soften the shadows of a person standing against the sun. Credit: Lisa Attivissimo.

of an atmosphere; it's lit mainly by the *reflection* of light from nearby objects, which does not require an atmosphere. So reflection works fine in a near-vacuum such as the Moon.

Atmospheric diffusion or scattering is the phenomenon that causes, for example, the glow around a streetlight at night.

Shadows on Earth or on the Moon are instead lit mainly by the *reflection* of light on nearby objects. Photographers often use reflection (not atmospheric diffusion) to soften the shadows of a portrait by placing the subject close to a brightly lit wall or by using custom-built reflective panels, which are kept out of frame, as in the example in Figure 5.18-3.

On the Moon, this reflection is provided mainly by the ground, which is in full sunlight and is all around the astronauts, who are wearing a highly reflective white spacesuit.



Figure 5.18-4. Astronaut Bruce McCandless works in the vacuum of space outside the Shuttle (1984). Photo GPN-2000-001075.

The fact that an atmosphere is not needed to obtain a fill light in backlit pictures is demonstrated for example by Space Shuttle photographs, where the astronaut is in the vacuum of space but the light reflected by the surrounding surfaces and by the daylit Earth below is more than enough to soften the shadows.

In Figure 5.18-4, for example, the only source of direct light is the sun, but the white surfaces of the Shuttle cargo bay reflect enough of this sunlight to lighten the shadows on astronaut Bruce McCandless.

In other words, the explanation of this alleged anomaly is the same one given for the objection that astronauts in shadow are strangely well-lit. In that case, the conspiracists argued that the counterintuitive lighting was evidence of studio spotlights, whereas here they claim that shadow softening is evidence of an atmosphere. In both instances their claims turn out to be factually incorrect.

5.19 How come Apollo 11's boulder field isn't in the photos?

IN A NUTSHELL: *Actually, it is. The large boulders that Neil Armstrong says he overflew just before landing are faintly visible in the Apollo 11 photographs, but only in the high-resolution scans, because they're over 400 meters (1,300 feet) away and therefore appear tiny. Moreover, from the landing site they were upsun and therefore impossible to document in detail. However, these boulders are clearly visible in the pictures of the landing site taken in 2009 by the Lunar Reconnaissance Orbiter.*

THE DETAILS: Descriptions of the first Moon landing often mention dramatically that the automatic systems of the lunar module were taking astronauts Neil Armstrong and Buzz Aldrin straight into a dangerous crater surrounded by large boulders, but Armstrong took manual control and flew on to find a clear landing spot. This took so much time that the Apollo 11 astronauts landed with less than a minute of fuel to spare.

This episode is frequently used to point out the advantages of having a pilot on board to deal with the shortcomings of automatic systems and to stress how difficult and dangerous it was to land on the Moon.

However, the photographs taken by Aldrin and Armstrong while they were on the Moon show no trace of this alleged nearby boulder field. As far as the eye can see, the landing site is flat and featureless. Perhaps, it is argued, this detail was added to embellish the story and make it more exciting.

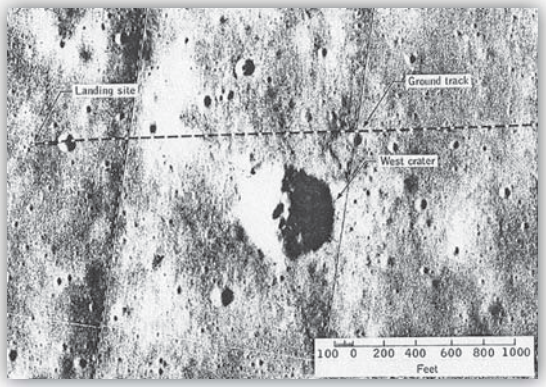


Figure 5.19-1. The final portion of the ground track of Apollo 11. The landing trajectory ends on the left. The large crater at the center is known as West Crater. Detail from the Apollo 11 Mission Report (1969).

That's a doubt that we can dispel by looking at the data. Apollo 11's landing path, or *ground track*, is published in the *Apollo 11 Mission Report* and shown partly in Figure 5.19-1.

Armstrong's decision is transcribed in the 1969 *Technical Debrief*; the *Apollo 11 Preliminary Science Report* identifies the boulder-littered crater as *West Crater*. This crater is visible in the photograph shown above, but no boulders can be seen. This, it turns out, is simply due to its low resolution.

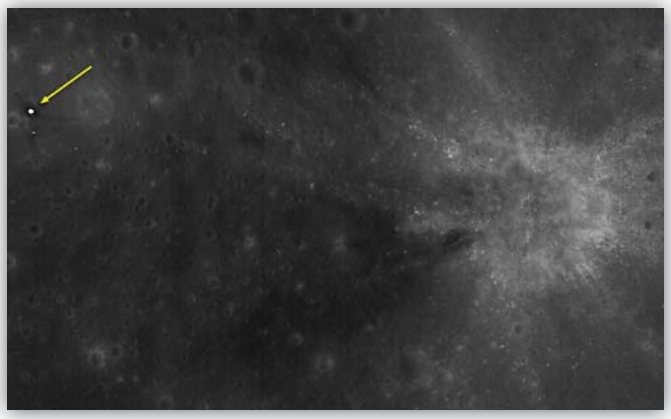


Figure 5.19-2. The Apollo 11 landing site as imaged by the LRO probe in 2009. West crater is on the right. The arrow indicates the descent stage of the lunar module (the white dot).

Today, however, we have the high-resolution pictures of the Apollo 11

landing site acquired by the Lunar Reconnaissance Orbiter (LRO) probe since 2009. These images show the boulders quite clearly, as in Figure 5.19-2.

In particular, image M109080308RE, taken by the LRO probe and shown partially in Figure 5.19-2, captures West Crater in very fine detail. It shows that the crater is indeed filled and surrounded by boulders, which stand out as white dots. Their size can be grasped by noting that the white dot indicated by the arrow in the figure is the central part of Apollo 11's descent stage, which is about four meters (13 feet) wide without the landing legs.

The boulders can't be seen in the photographs taken by the Apollo 11 astronauts while they were on the lunar surface for two main reasons. The first one is that they were too far away: the scale the figures indicates that the center of West Crater was over 500 meters (1,600 feet) from the LM.

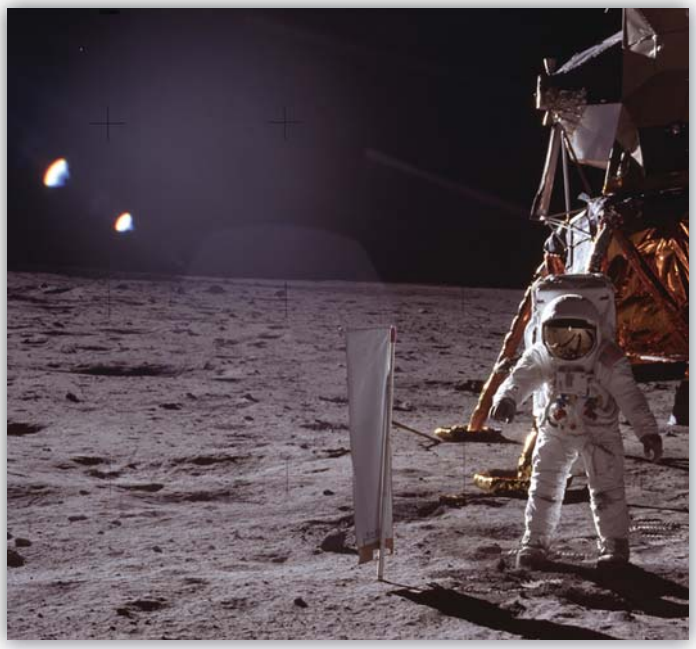


Figure 5.19-3. Detail of photo AS11-40-5873 (Apollo 11), taken almost fully upsun. West Crater is on the horizon, to the left.

The second reason is that in order to take any pictures of West Crater, the astronauts would have had to point the camera towards the sun. This would have produced very poor, lens flare-filled photographs, so no photos were taken in that direction. In some pictures, West Crater is at the very edge of the frame and a few boulders can be glimpsed, but only in the high-resolution versions, as shown for example in Figure 5.19-3 and Figure 5.19-4.



Figure 5.19-4. The left portion of photo AS11-40-5873 (Apollo 11), enhanced to show West Crater and some adjacent boulders more clearly.

However, there's another source of photographic coverage of the area supplied by the Apollo 11 astronauts: the 16 mm color film shot during descent and landing. Since the lunar module flew past West Crater as it descended to land, the boulder field should be quite visible in this film.

Indeed it is: Figure 5.19-5 is a frame from that footage, taken from an altitude of about 120 meters (390 feet) with the camera looking down almost vertically. The boulders are large enough to be distinctly visible from that height and cast conspicuous shadows.

As a further cross-check, researchers Rene and Jonathan Cantin produced and published a video (Figure 5.19-6) that matches the Apollo 11 landing film against a photograph of the same area taken in 1967 by an uncrewed Lunar Orbiter probe.

In other words, instead of being evidence of conspiracy, the issue of the apparently missing boulders is a great opportunity to perform cross-checks on the available NASA documents and verify that they are mutually consistent.



Figure 5.19-5. Boulders near the landing site, seen from approximately 120 meters (390 feet), in a frame of the 16 mm film of the landing.



Figure 5.19-6. Comparison of Apollo 11 onboard footage and Lunar Orbiter images of the landing site. Credit: Rene and Jonathan Cantin.

5.20 Why are the tracks of the Moon car missing?

IN A NUTSHELL: *They're not missing: they're wiped out by the astronauts' bootprints, or they didn't form at all because the special open-mesh wheels didn't leave deep tracks and because the astronauts often turned the buggy around by lifting it at one end, without leaving wheel tracks.*

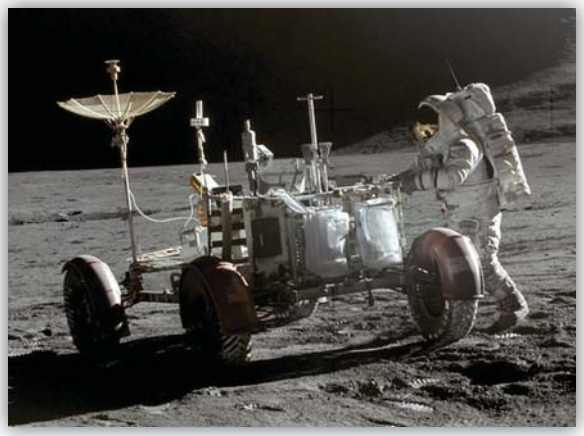


Figure 5.20-1. Detail of photo AS15-86-11603 (Apollo 15).

THE DETAILS: In some photographs there's no sign of the tracks formed in the lunar dust by the wheels of the electric buggy (the Lunar Rover), neither in front of the vehicle nor behind it.

Yet the same lunar soil clearly registered the astronauts' bootprints. According to some Moon hoax theorists, the studio crew forgot to add tire marks when they placed the Rover on the set, thus revealing the fakery.

Here's how the Davidicke.com forum discussed this claim:



Figure 5.20-2. Alleged evidence of fakery: no wheel tracks. From Davidicke.com (post no longer available online).

> And here we see an Apollo 17 astronaut making emergency repairs on the buggy's fenders with duct tape (How he did that with his gloves on is debatable!).
>
> Ok. So far, so good. Now check out the pic where the repair has been done. There are foot marks near the fender, BUT WHAT HAPPENED TO THE BUGGY'S TIRE MARKS? How did it get there? Was the buggy placed there by a crane? This has nothing to do with gravity or an atmosphere, but shows the hidden side of what NASA did or did not do.

Actually, there are several reasons why the tracks are sometimes missing. In some photographs the astronauts simply walked over the tracks and wiped them out with their bootprints. To take pictures of the Rover, they had to get off the vehicle and walk away from it, so it makes sense that they sometimes walked over the freshly formed tracks.

Indeed, this is the case in the image presented as alleged evidence: a little research reveals it to be a cropped version of photograph AS17-137-20979, which documents the improvised repair of the Rover's fender by the Apollo 17 astronauts. To make this repair (using duct tape, clamps and

laminated maps), they obviously had to walk all around the damaged fender, thus erasing any wheel tracks.

If we look at the complete photograph (Figure 5.20-3), which is in color and far less contrasted and more detailed than the version presented by the Moon hoax proponents, we find that astronaut bootprints are visible at the bottom and on the right. It is interesting to note that the pro-hoax version is conveniently cropped so as to hide almost all the bootprints.

In other photographs, the vehicle was traveling over an area that didn't have a deep layer of dust (like the Earth, the Moon isn't identical everywhere) and therefore the wheels of the Rover left faint tracks that can be seen only in the high-resolution versions of the Apollo photographs but are

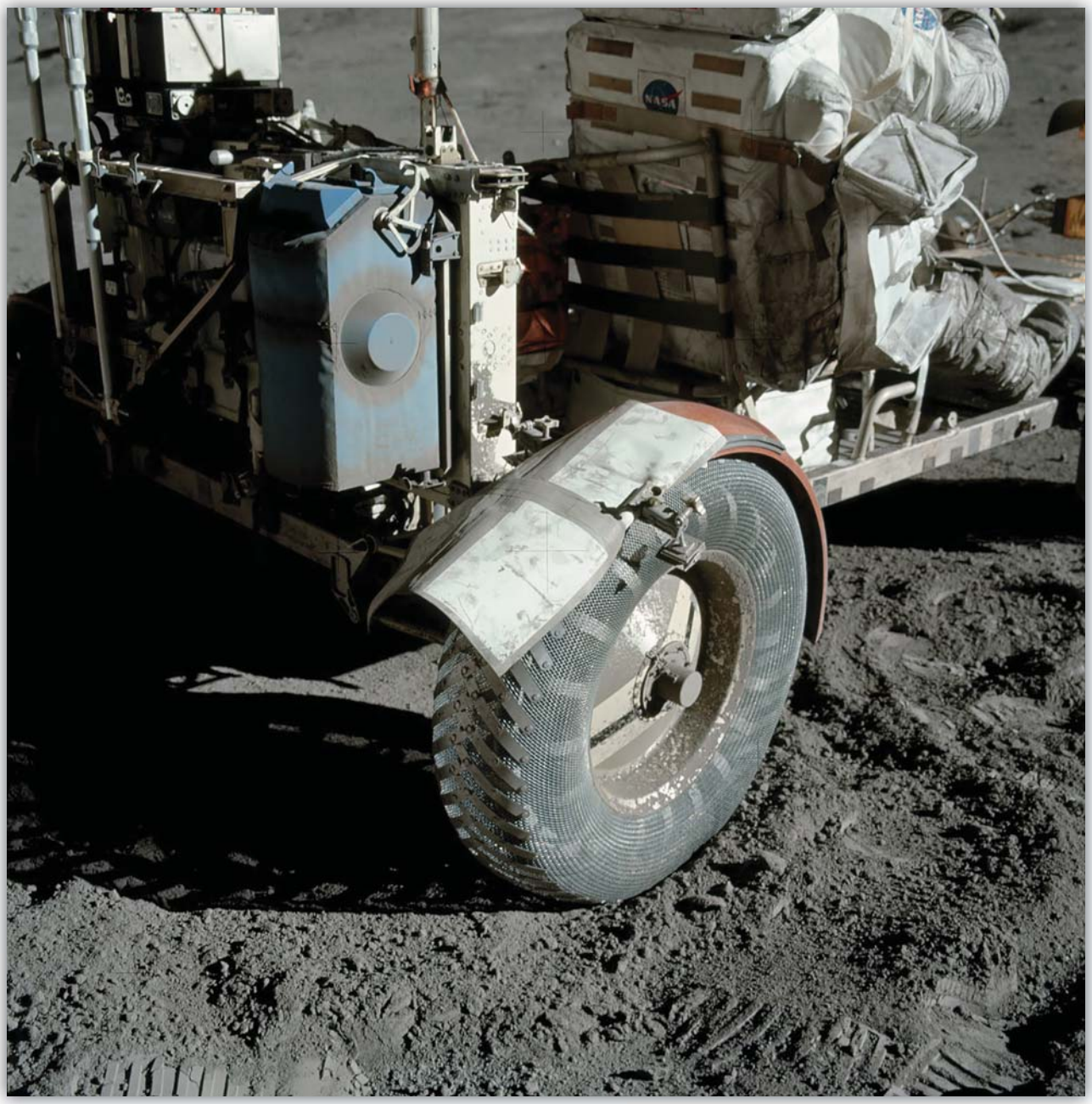


Figure 5.20-3. The uncropped version of photo AS17-137-20979 with its original colors and shades.

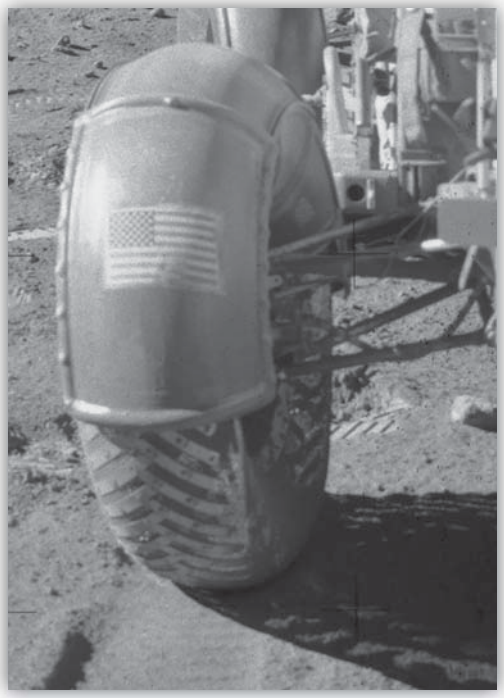


Figure 5.20-4. Detail of photo AS16-108-17620. Note the shallowness of the track and the light that passes through the mesh of the wheel, as revealed by the gaps in the wheel shadow.

invisible in the poor copies frequently used by hoax theorists.

It should also be noted that the wheels of the Rover didn't have tires or a solid tread. They were made of an open metallic mesh on which spaced titanium laminas were applied in a chevron pattern, as shown in Figure 5.20-4.

The fine lunar dust would pass through the mesh like sand through a sieve and therefore didn't leave the sharply outlined tracks of a normal solid tire tread, which compacts the ground.

This frequent lack of tracks is due also to another reason, which is rather counterintuitive: the Rover was extremely light, and on the Moon everything weighs one sixth of what it weighs on Earth. The Rover weighed about 210 kilograms (462 pounds) on Earth, so on the Moon it weighed only about 35 kilograms (77 pounds); therefore the astronauts could easily lift one of its ends.

Indeed, that's what they often did when they needed to turn the Rover around: they simply lifted one end and turned it. This was actually a scheduled maneuver during the extraction of the Rover from the LM: the Moon car had to be turned through 180 degrees to point it away from the LM.

This low weight was distributed over the contact area of the four wheels and therefore the Rover applied a very low pressure to the ground even when it was carrying the astronauts, whose weight was likewise reduced by the low lunar gravity. Accordingly, the wheels did not dig deeply into the soil, producing only shallow tracks.

5.21 How come NASA has published retouched photographs?

IN A NUTSHELL: *Merely to repair scratches or blemishes in old scans of duplicates. The high-resolution master scans available through NASA show no such signs of fixing. Besides, if they had been retouched to hide something, it would mean that they were actually taken on the Moon; otherwise it would have been easier to reshoot them properly on the alleged movie set.*

THE DETAILS: Perhaps surprisingly, it is quite true that some NASA websites have published badly touched-up versions of the Apollo images. For example, image S69-40308, posted for several years at *Spaceflight.nasa.gov* (Figure 5.21-1), is crudely retouched by cutting and pasting in its top right part (Figure 5.21-2). The alteration is revealed by the unusually repeating patterns in the lunar soil.

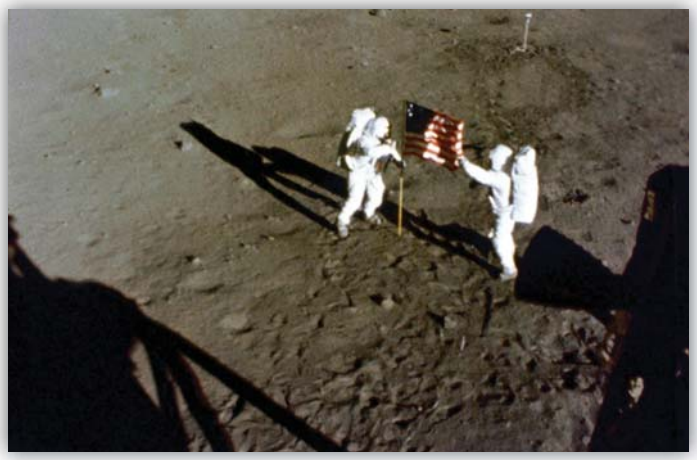


Figure 5.21-1. Image S69-40308, a frame from the Apollo 11 16 mm film, as shown at Spaceflight.nasa.gov *in February 2010. Note the repeating patterns in the top right corner. Source: Archive.org.*

Copy-pasting is often used in digital retouching to cover unwanted details or a flaw in the picture. Here the touch-up is so blatant that even dust specks that were on the scanned film have been conspicuously duplicated.

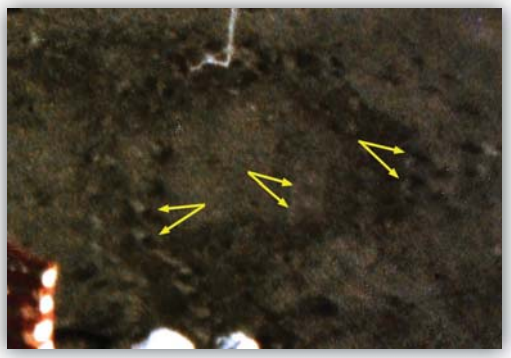


Figure 5.21-2. Detail of the preceding image. The arrows indicate the duplicated regions.

However, this doesn't mean that NASA systematically retouches its pictures and is concealing embarrassing or top-secret details: it seems rather unlikely that a high-level cover-up would publish such clumsy and easily detectable fakes. Besides, NASA websites also offer other copies of this image that have not been retouched (for example at the *Apollo Lunar Surface Journal*). Further copies are available in private collections of vintage prints and don't exhibit this retouching). These copies reveal that the copy-pasting is merely correcting defects in scans taken from old, damaged duplicates of the original films. It's just a clean-up, not a deception.

It might seem unusual for NASA to publish such shoddy versions of the Apollo photographs, but contrary to the beliefs of many Moon hoax theorists the US space agency is not a wealthy, monolithic government body. It's a big bureaucracy with many departments that often work in isolation from each other and with limited funds and equipment.

The end result is that various NASA departments each published on the Internet their own versions of the Apollo visual record, using the film copies that they had in their archives. In many cases those film copies were duplicates of duplicates made years or decades earlier, faded by time and damaged by handling.

Having no funds allocated for a fresh scan of the Apollo images, the departments used whatever they had, as Dave Williams of NASA Goddard Spaceflight Center told me in personal correspondence in September 2003. The same process generated the alleged letter C on a rock, debunked earlier in this chapter.

The unretouched, properly scanned originals are available from four main Internet reference sources: the *Apollo Lunar Surface Journal*, the Lunar and Planetary Institute, the Gateway to Astronaut Photography of Earth and the Apollo Archive. Details and Internet addresses are in the *References* section of this book.

Actually, any claim that NASA is retouching photos to hide something leads to a contradiction of Moon hoax theories. If the photographs had been retouched beyond mere scratch or blemish correction, this would mean that they were actually taken on the Moon, otherwise it would have been easier to just go back to the set and take them again properly.

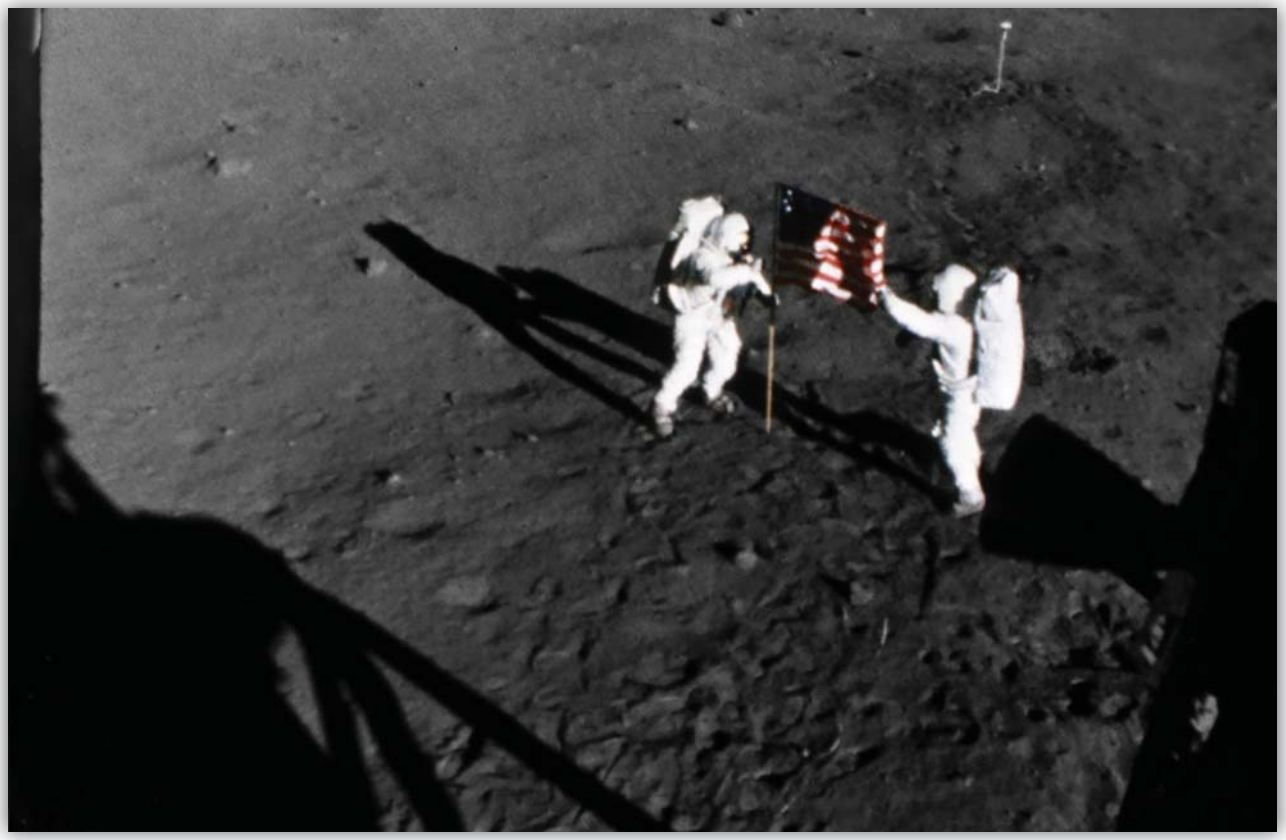


Figure 5.21-3. A better scan of the same 16 mm frame, taken from Spaceflight.nasa.gov in 2018.

5.22 How come the EVA photo of Michael Collins is fake?

IN A NUTSHELL: *Because a conspiracy theorist altered the original to make it look fake.*

THE DETAILS: According to Moon hoax theorist Ralph Rene, the autobiography of lunar astronaut Michael Collins, *Carrying the Fire*, contains a faked spacewalk photograph (Figure 5.22-1).



Figure 5.22-1. The allegedly faked photograph, as shown by Rene.

Rene claims that the autobiography describes this picture as Collins during a spacewalk in the Gemini 10 mission (1966), although it's actually a photo taken during training inside an aircraft and then (says Rene) altered by NASA (Figure 5.22-2).



Figure 5.22-2. The other version of the photograph.

According to Rene's book *Nasa Mooned America!*, these pictures *"absolutely prove that NASA began to doctor photos three years before the Apollo missions allegedly landed men on the Moon"*. Rene makes the same allegation in Willy Brunner and Gerhard Wisnewski's documentary *Die Akte Apollo*, broadcast by German TV station WDR in 2002 and by Italian national network Rai in 2006.

Some basic fact-checking shows that the allegedly doctored version of the photograph does not appear in any NASA publication. It only appears in some editions of the Collins autobiography (the 1974 edition by Farrar, Straus & Giroux and the 1975 edition by Ballantine Books) and even there it is *not* described as being taken during the Gemini 10 spacewalk. The caption clearly states that it was taken during training in an aircraft.

Indeed, Collins himself notes with regret, in his book, that there are no photographs of his Gemini 10 spacewalk (*"One of the great disappointments of the flight was that there were no photos of my spacewalk. [...] I was really feeling sorry for myself, unable to produce graphic documentation for my grandchildren of my brief sally as a human satellite"*).

In 2003, space historian James Oberg offered Rene 10,000 dollars for any edition of the Collins autobiography that described the doctored photograph as a spacewalk snapshot. Rene was unable to provide one, and so far nobody else has either.

In their documentary, German authors Brunner and Wisnewski resort to misleading editing in order to support Rene's allegation: first they show the cover of *Carrying the Fire* and then they crossfade to a page that contains the allegedly doctored photograph with the caption *"Gemini 10 space walk"*, as shown in Figure 5.22-3.



Figure 5.22-3. The Brunner and Wisnewski documentary Die Akte Apollo *crossfades the cover of the Collins autobiography with a page from Rene's book (stills from the Italian broadcast of the documentary, 2006).*

However, this page is not taken from *Carrying the Fire*: it's taken from Rene's book *Nasa Mooned America!,* as revealed by the text on the page, which can be read in freeze-frame.

In summary, the entire allegation of fakery against Michael Collins and NASA is made up. Instead of demonstrating *"absolutely"* that the US space agency faked a photo, it demonstrates that some Moon hoax theorists are willing to stoop to falsehoods and editing tricks in order to prop up their claims.

5.23 How could the astronauts take so many photos in such a short time?

IN A NUTSHELL: *By taking many of them in rapid bursts of 8-12 shots to form panoramic sequences; for example, almost half of the pictures of the Apollo 11 moonwalk were taken in this way, as the astronaut turned around on the spot. The same applies to the other missions.*

THE DETAILS: Conspiracy theorist Jack White claims that the astronauts didn't have enough time to take all the photographs that NASA says were taken on the Moon and also get some work done. Therefore, he argues on his website Aulis.com, some of the pictures must be fake.

White says that the Apollo missions, according to NASA's reports, spent a total of 4,834 minutes on the Moon, taking 5,771 photographs. This is equivalent to an average of 1.19 photographs per minute (one photograph every 50 seconds) throughout the duration of all the moonwalks. White says that the Apollo 11 crew reached an even higher average, with one photo every 15 seconds (121 shots in 151 minutes).

The Apollo 11 figures given by White are almost correct: the film magazine used during mankind's first moonwalk contains 123 photographs (not 121) taken outside the lunar module (catalog numbers AS11-40-5850 to 5970, plus AS11-40-5882A and 5966A), and Armstrong and Aldrin's excursion lasted two hours and 31 minutes according to the *Apollo Definitive Sourcebook*.

Taking 123 photographs in 151 minutes, however, doesn't yield an average of one picture every fifteen seconds. The actual average is less than one picture per minute. How does White get to 15 seconds? He introduces *"arbitrarily"* (as he puts it) a value of two hours to take into account the other activities of the astronauts:

> *Let's arbitrarily calculate a MINIMUM time for these tasks and subtract from available photo time.*

Why two hours and not two and a quarter, or one and a half? White doesn't explain the reason for his choice. It's obviously quite easy to get impossible results if you alter the data by introducing arbitrary values.

White also fails to specify that the astronauts took many sets of photographs from the same place, without wasting time getting into position and aiming again for each picture, so that the photos could be later assembled into panoramic views. In creating a panoramic sequence it's quite easy to take a dozen photographs in a few seconds (try this

yourself). This alters considerably the average time required. Here are a few examples.

Photos AS11-40-5881 to AS11-40-5891 (11 frames, almost 10% of all of the Apollo 11 moonwalk photographs) were shot by Buzz Aldrin as he turned around on the spot to form the panoramic view shown in Figure 5.23-1.



Figure 5.23-1. Panoramic view assembled by Dave Byrne for the Apollo Lunar Surface Journal *with photos AS11-40-5881 to 5891.*

Photographs AS11-40-5905 to AS11-40-5916 (12 frames, 10% of the total) compose another panoramic view, again taken by Aldrin and shown assembled in Figure 5.23-2.

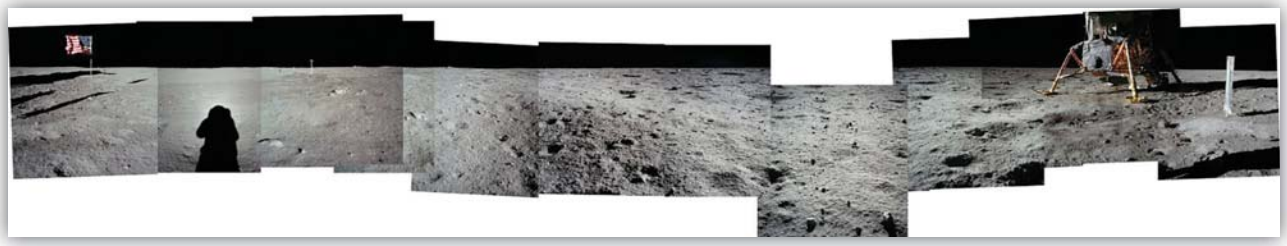


Figure 5.23-2. Panoramic view assembled by David Byrne for the Apollo Lunar Surface Journal *with photos AS11-40-5905 to 5916.*

Frames AS11-40-5930 to AS11-40-5941 (12 shots) were taken by Neil Armstrong to form the panoramic view shown in Figure 5.23-3.



Figure 5.23-3. Panoramic view assembled by Brian McInall for the Apollo Lunar Surface Journal *using photos AS11-40-5930 to 5941.*

Figure 3.15 of NASA's *Apollo 11 Preliminary Science Report* features a map which shows the location and direction of every photograph taken during the Apollo

11 excursion (Figure 5.23-4). The number of photographs taken in rapid sequence from the same location is quite considerable.

This map indicates that photographs 5850 to 5858 (9 shots) and 5954 to 5961 (8 shots) form two more panoramic views in addition to the ones shown above.

In summary, therefore, during the Apollo 11 moonwalk 52 photographs out of 123 belong to panoramic sequences that were taken in quick bursts, without moving and refocusing between shots.

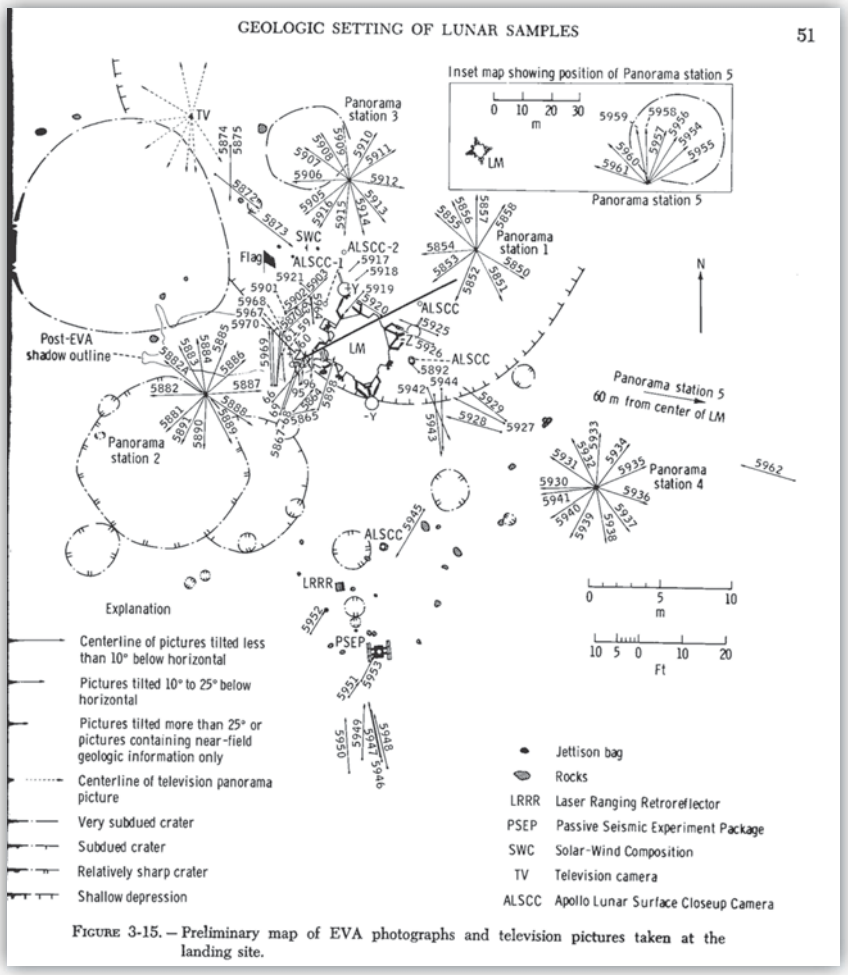


FIGURE 3-15. — Preliminary map of EVA photographs and television pictures taken at the landing site.

Figure 5.23-4. Map of the locations and directions of every photograph taken during the Apollo 11 moonwalk.

The same applies to the other moonwalks, in which the astronauts took many panoramic sets (Figure 5.23-5 is an example from Apollo 16) and also took several *stereo pairs*, i.e., two photographs taken almost simultaneously from two slightly different viewpoints, which can be combined to produce 3D images.



Figure 5.23-5. Panoramic view assembled using photos AS16-113-18313 to 18330 by Lennie Waugh for the Apollo Lunar Surface Journal*.*

Once all the facts are on the table, it's no longer surprising that the astronauts took so many photographs. What is surprising, instead, is that Jack White, who claims to have researched the Apollo missions thoroughly before making his allegations of fraud, has failed to consider this simple explanation, which is extensively documented and is self-evident from the photographs themselves.



Figure 5.24-1. The allegedly faked shadowless saluting astronaut.

5.24 Why is this astronaut's shadow missing?

IN A NUTSHELL: *Because he was jumping when the snapshot was taken and so his shadow is displaced sideways and isn't visible in cropped versions of the picture; full versions show it clearly.*

THE DETAILS: The photograph shown in Figure 5.24-1 is often claimed by hoax theorists to be fake because the astronaut quite conspicuously lacks a shadow.

A patient search through the Apollo image archives reveals that it's a cropped version of photo AS16-113-18339, taken during

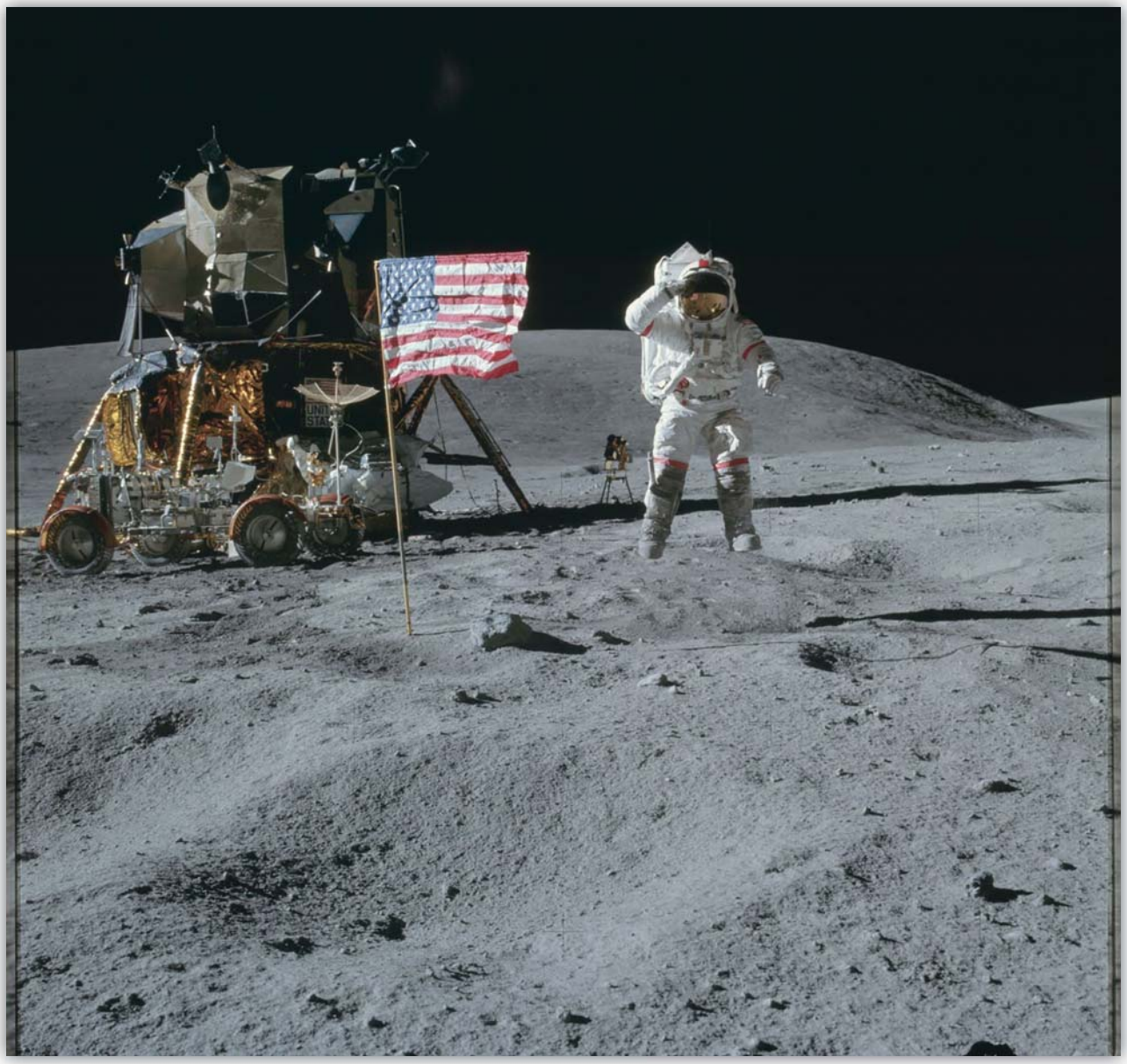


Figure 5.24-2. Detail of photo AS16-113-18339. John Young's shadow is displaced towards the right because the picture was taken while he was jumping vertically.

the Apollo 16 mission by Charlie Duke. It portrays his commander, John Young, as he salutes the flag.

Knowing the context in which the picture was taken provides the answer to the missing shadow. As noted in the mission reports and transcripts, and as recorded by the video footage of the mission, Young jumped vertically during the salute and Duke caught him in midair in the photograph. That's why there's no shadow at Young's feet: the shadow is displaced downwards and to the viewer's right, as occurs normally when someone is photographed during a vertical leap with a low sun angle.

An uncropped scan of the photograph (Figure 5.24-2) shows that the astronaut does indeed cast a shadow in the center right portion of the picture.

John Young's leap was seen by the TV camera mounted on the Rover and was televised live to Earth (Figure 5.24-3).



Figure 5.24-3. Live color TV of John Young's jump on the Moon, from the documentary Nothing so Hidden *[http://tiny.cc/w8glbz].*

5.25 Why is the United States marking on the LM so bright?

N A NUTSHELL: *Because it's reflective and it's lit by the glare from the daylit lunar surface. In fact it's equally readable in the pictures taken during LM testing in Earth orbit.*

THE DETAILS: There are claims that the *"United States"* lettering on the descent stage of the lunar module has been brightened or even lit with a spotlight for propaganda purposes, in order to point out that the Moon landing was an American accomplishment. With the Sun behind the LM, it is said, the lettering in shadow should not be so clearly visible.



Figure 5.25-1. An image from Italian website Leggendemetropolitane.net (2003) in which the "United States" lettering is allegedly too bright.

Fox TV's show *Did We Land on the Moon?* also raises the same question:

> Narrator: *...in this picture with the sun behind the Lunar Module, the front of the craft is clearly visible, the words "United States" are crisp and clear. How could these backlit pictures be so detailed?*
>
> Bart Sibrel: *It's because there's more than one light source, means they're not on the Moon*.

These words are accompanied by these unidentified photographs (Figure 5.25-2).

By patiently searching through the entire set of Apollo photographs it is possible to identify the photographs in dispute. They are respectively AS15-88-11866, (Figure 5.25-3) and AS14-66-9306 (Figure 5.25-4).



Figure 5.25-2. The images of the "United States" lettering shown in the Fox TV program Did We Land on the Moon?



Figure 5.25-3. Photo AS15-88-11866.

Actually, the lettering *is* lit, but not artificially: it receives the natural reflection of sunlight from the daylit lunar surface and the surrounding objects. Indeed, not only the lettering but the entire shadow side of the lunar module is lit by this reflection.

In the case of photo AS15-88-11866, in particular, the "*United States"* marking faces the bright white deck of the Modularized Equipment Stowage Assembly (MESA). Part of this deck is in full sunlight and therefore it is quite reasonable to assume that it reflects more than enough light to brighten the marking.

Moreover, the photographs presented by conspiracy theorists are, as usual, of very poor quality and have extreme

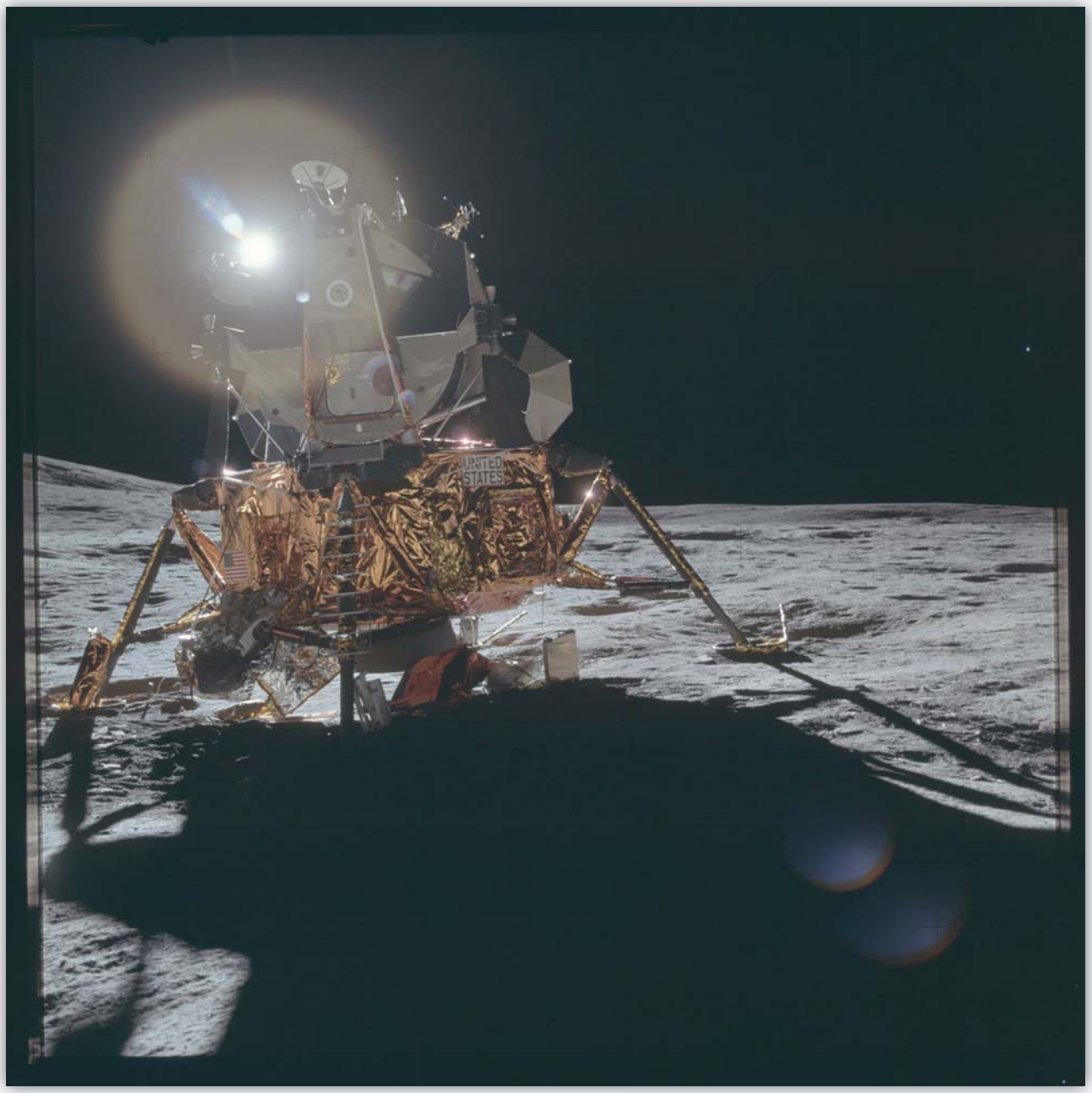


Figure 5.25-4. Photo AS14-66-9306.

contrast, which makes the shadow regions darker than they actually are.

The fact that the lettering did not require special light sources to stand out in photographs is demonstrated by the fact that it is equally visible in pictures that are not questioned by conspiracy theorists, such as the photographs of the Lunar Module in Earth orbit during Apollo 9 (Figure 5.25-6), where it is clearly visible even though it is only lit by the sunlight reflected by the Earth below.



Figure 5.25-5. Detail of photo AS15-88-11866.

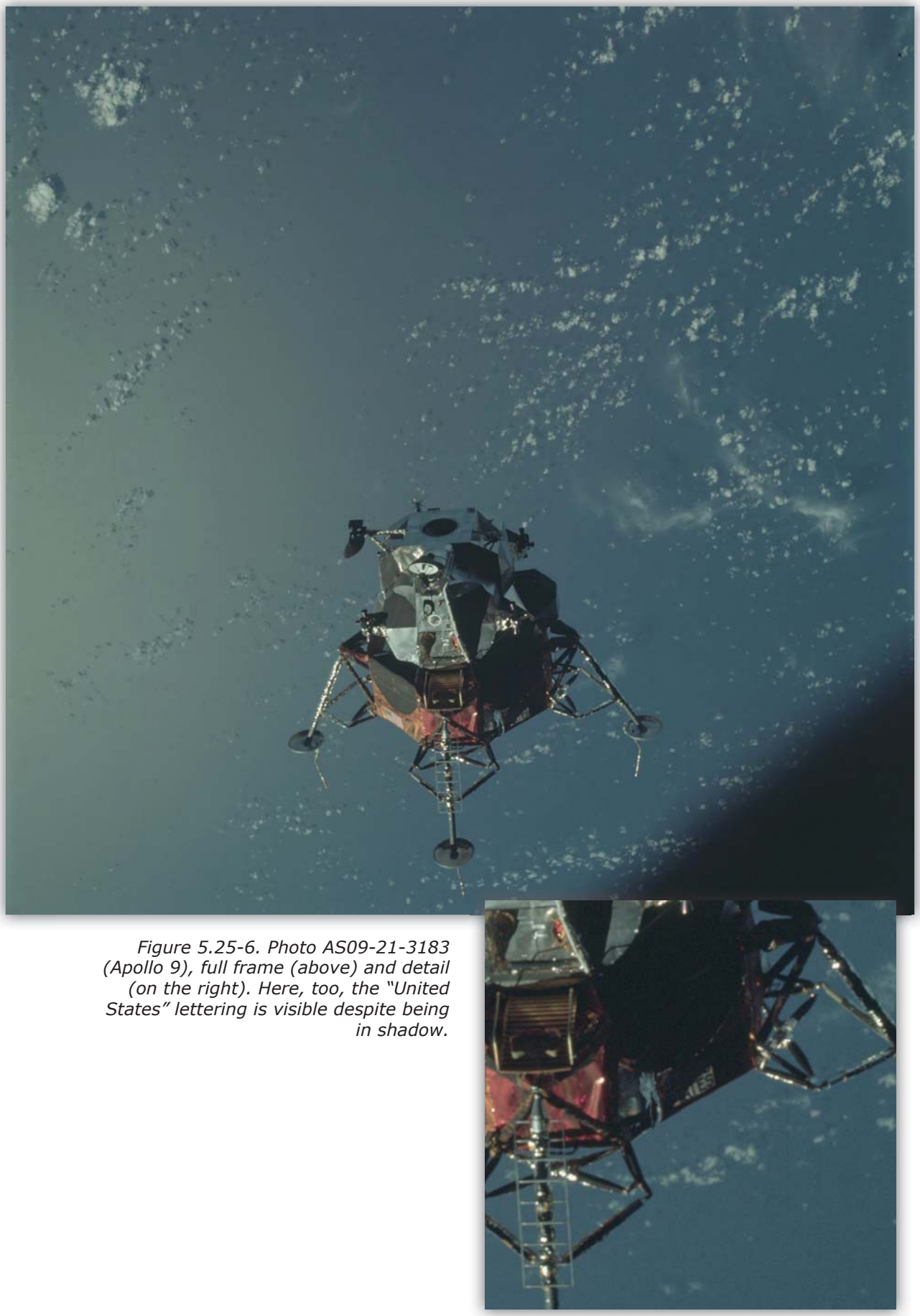


Figure 5.25-6. Photo AS09-21-3183 (Apollo 9), full frame (above) and detail (on the right). Here, too, the "United States" lettering is visible despite being in shadow.

5.26 Why do Aldrin's boots shine in shadow? Are they lit by a spotlight?

IN A NUTSHELL: *No. The sheen on Buzz Aldrin's boots is not caused by a studio spotlight but by the bright sunlight reflected by Armstrong's reflective white spacesuit as he stands in the sun. The Moon boots in museums have a dull finish because they're worn, but they were initially coated with lubricant which made them quite shiny when brand-new and clean. Also, the contrast and brightness of the photo used to present this apparent mystery have been boosted unrealistically.*

THE DETAILS: In Apollo 11 photographs AS11-40-5866 and 5869, Aldrin's boots have a bright white highlight that looks like a reflection from a flash or a bright spotlight. This is suspicious, it is claimed, because Aldrin is standing in shadow, no flashes or studio lights were taken to the Moon, and Apollo Moon boots had a dull gray finish. Therefore, it is claimed, obtaining this kind of highlight would have required a very powerful local light source. An example of the controversial reflection is shown in Figure 5.26-1.

First of all, the highlight isn't really as bright as it appears in the top photo shown above, which is a version often used in pro-conspiracy publications and in which contrast and brightness have been exaggerated to the point of losing all shadow detail. The bottom photo shows the same detail, but taken (without processing) from the high-resolution scan publicly available at NASA's GAPE site (*eol.jsc.nasa.gov*). The difference is quite remarkable.

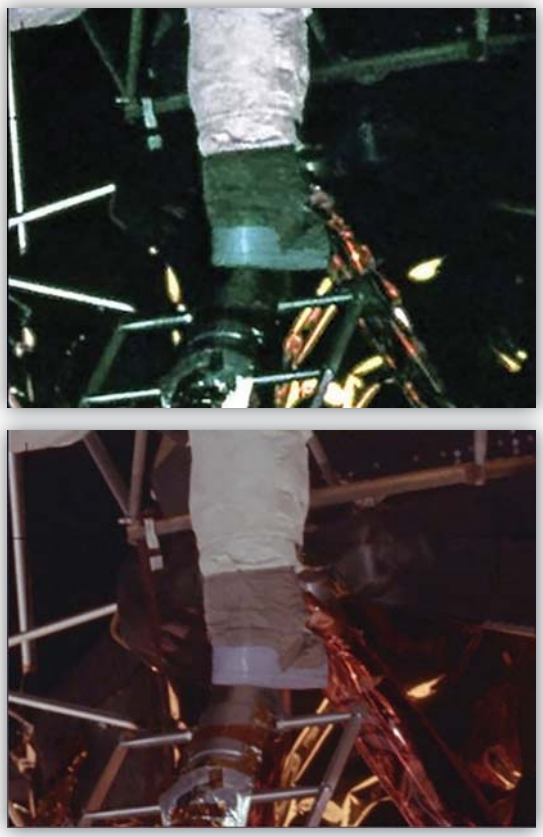


Figure 5.26-1. Detail of photo AS11-40-5866 as often circulated in Moon hoax sites (top) and as found in direct scans of the original picture (bottom).

Nevertheless, boots with a dull finish shouldn't produce a highlight of any sort. But if we examine the manufacturing process of these boots, it turns out that there's a very good reason for this sheen. The silicone rubber overshoes that formed the heel and sole of the boots were made in a mold. A lubricant was applied to the inside of the mold to prevent the silicone from sticking, so when the overshoe was removed from the mold it was coated with this lubricant. Archival footage of the process shows that brand-new Apollo overshoes were indeed shiny, and in the photographs of Aldrin's descent from the LM these overshoes were being used for the very first time, so they probably still had some lubricant on them.

Finally, there's the question of the light source. Conspiracy theorists jump to the conclusion that a studio spotlight was

used, but actually there's another powerful light source: Neil Armstrong's bright white spacesuit. If we look at the TV broadcast, we can see that at this point of the lunar excursion Armstrong is close to Aldrin and is standing in direct sunlight. Apollo spacesuits were designed to reflect as much sunlight as possible to avoid overheating, so Neil's suit is essentially acting as a man-sized reflector. In other words, the highlight is not proof of fakery.

5.27 Why is this photo of the LM on the moon so obviously fake?

IN A NUTSHELL: *Because it's not an official photo: it's a montage, clearly stated as such in the original source. This montage, however, sometimes is used as real even by experts and by some lunar astronauts. It is not part of NASA's official catalog of photos taken on the Moon and NASA has never claimed that it's authentic.*

THE DETAILS: The photograph shown in Figure 5.27-1 shows the Apollo 11 lunar module on the Moon, as Buzz Aldrin gets ready to climb down the ladder to set foot on the lunar surface. It is often used in books and articles about the Moon landings. It is featured in NASA's *Apollo Lunar Surface Journal* and has also been used by Apollo astronaut Walt Cunningham in his public talks.[3] But it's not a real photograph.

This photo is a montage created by Ed Hengeveld in 2008 by blending several real photographs of the Apollo 11 landing and by adding a computer-generated Sun.[4] But there is no

3 *Mission to the Moon*, Alan Dyer, Templar Publishing (2008); AstVintageSpace (Twitter.com, 2015); *So haben Sie Apollo 11 noch nie gesehen*, 20min.ch (2014); *The Apollo 11 Moon Landing Liveblog*, Gizmodo.com (2009); *ALSJ*, Nasa.gov; Walt Cunningham's public talk in Tradate, Italy, 2011 (Youtube.com).

4 The genesis of this image is explained in detail in Italian in *Sì, questa foto Apollo è un falso. Ma dichiarato*, ComplottiLunari.info (2015).

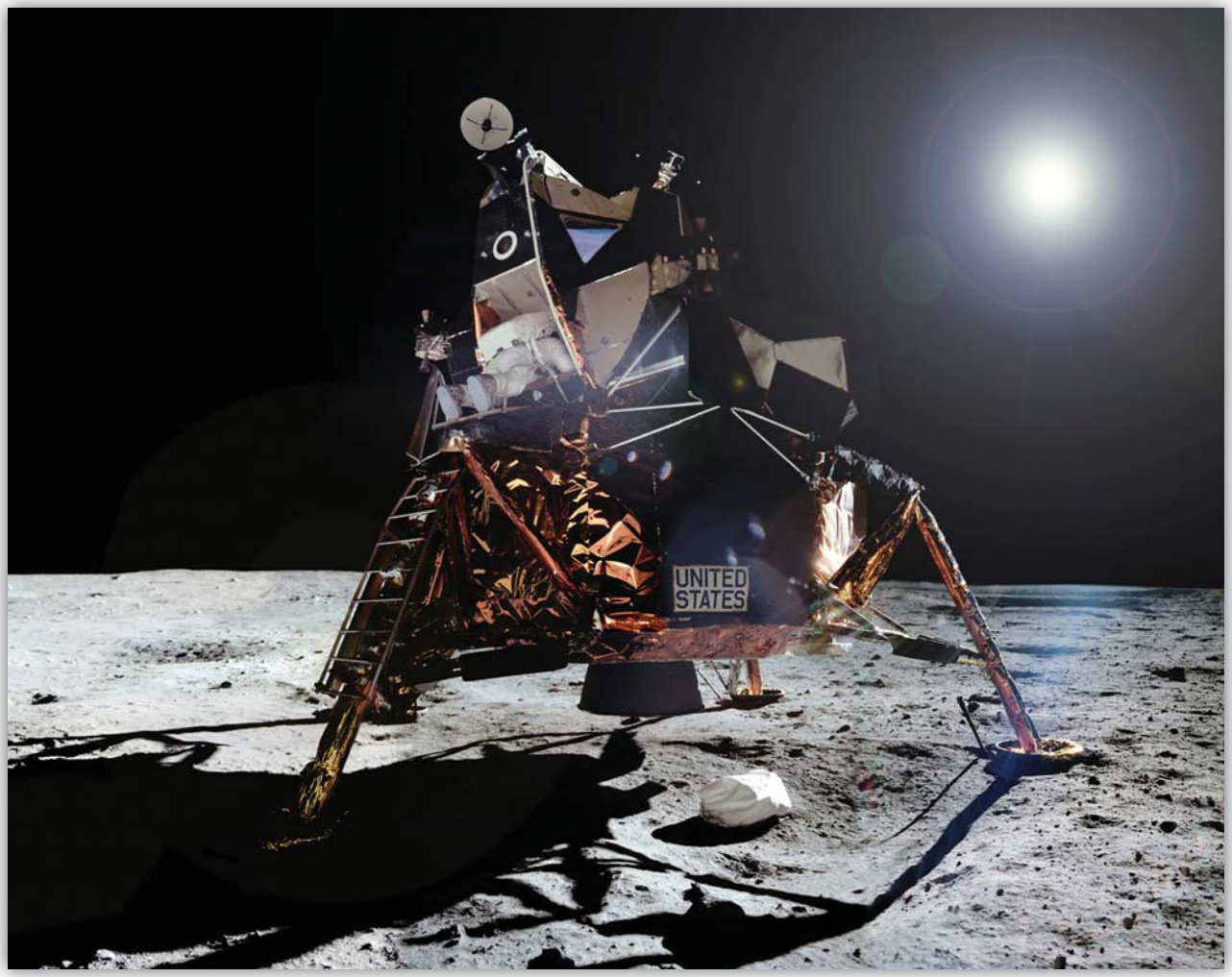


Figure 5.27-1. Composite image created by Ed Hengeveld (2008).

intent to deceive: neither its creator nor NASA claim it to be authentic.

This montage is indeed featured in the *Apollo Lunar Surface Journal*, but in the section of the *Journal* dedicated explicitly to montages and entitled *More Creativity - Fun and Inspiration*. It is not included in the official catalogs of Apollo 11 photographs.

An expert observer will notice several clues that this photo is not real: it's not square like all other Hasselblad photos taken on the Moon; there are no crosshairs (*reseau marks* or *fiducials*), whereas all the Apollo 11 photos taken outside the lunar module have them; the perspective is distorted and inconsistent; and the reflections of the sunlight on the right are not oriented correctly.

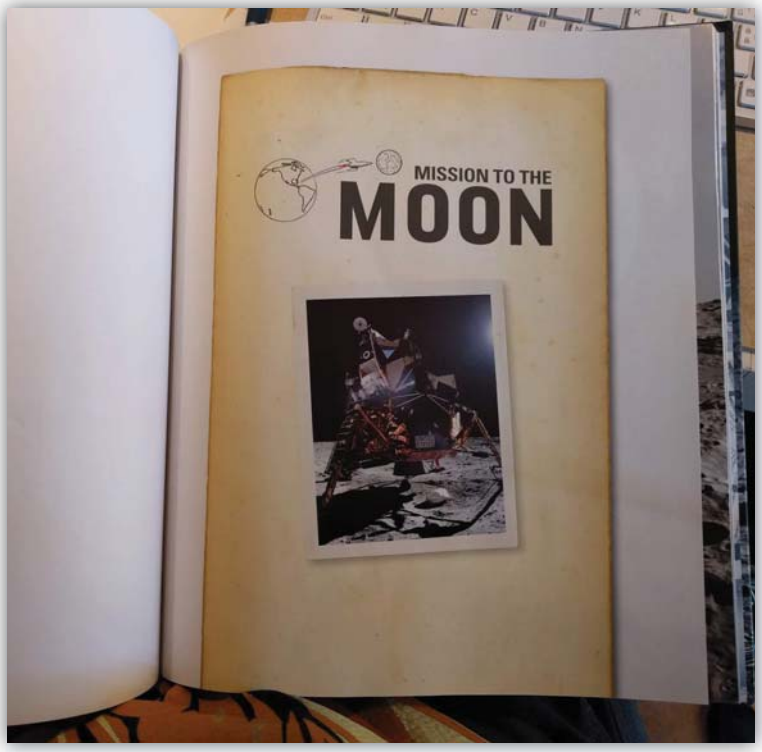


Figure 5.27-2. The montage presented at the beginning of the book Mission to the Moon by Alan Dyer (2008) without giving any indication of its true nature. From the author's personal collection.

However, as time goes by and direct recollections fade, there is the risk that this kind of realistic and believable composite image, might be presented unwittingly as authentic even by people who wish to document the moon landings and even by people who were part of the Apollo program, such as indeed Walt Cunningham, and that the original, non-deceptive intent of the photograph might be lost. And of course there's also the risk that conspiracy theorists might claim that this inadvertent use of a montage is evidence that NASA fakes its photographs.

5.28 Why is there a sharp dividing line between the foreground and the background?

IN A NUTSHELL: *Because it's the outline of the natural rises and hollows of the lunar terrain. The same effect occurs in desert photos taken on Earth.*

THE DETAILS: Many photographs of the Moon landings show a very sharp dividing line between the terrain in the foreground and the surface in the background.

According to some conspiracy theorists, such as David P. Wozney, this is the line that divides the floor of the movie set



Figure 5.28-1. Photo AS15-88-11866 (Apollo 15). On the left there is a double horizontal dividing line, which separates different colors and sharpness levels.

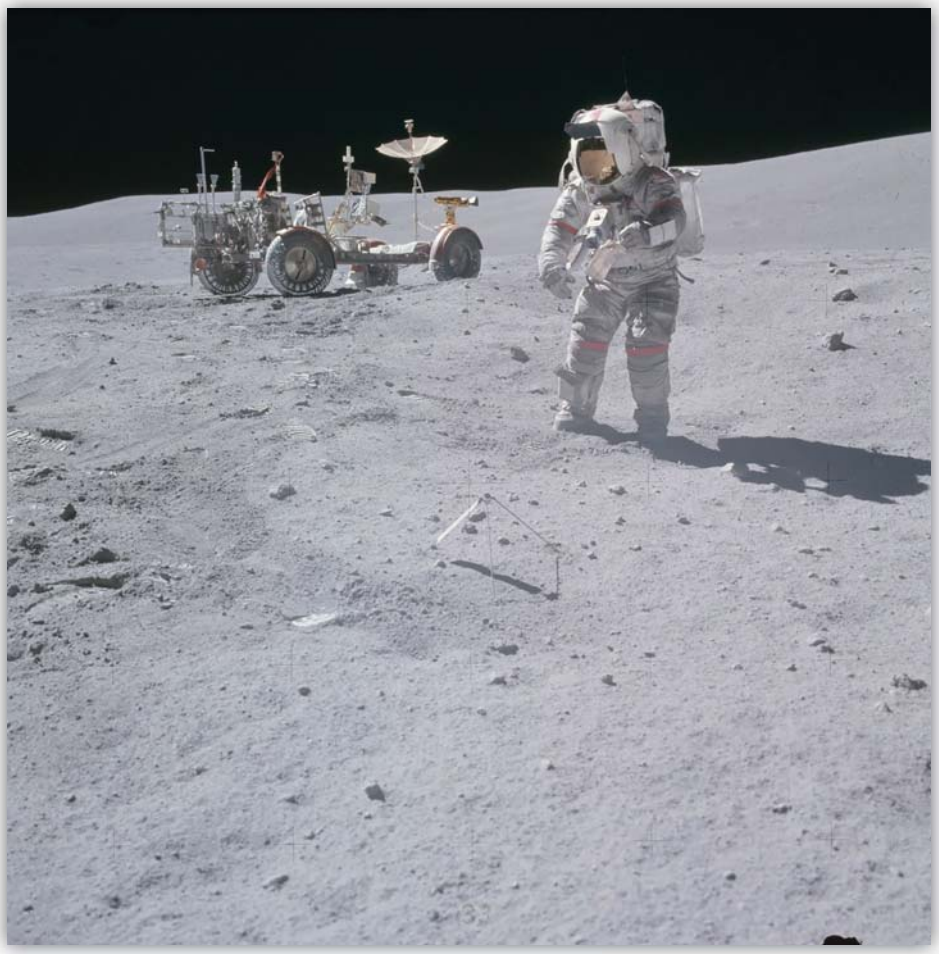


Figure 5.28-2. Photo AS16-117-18825 (Apollo 16).

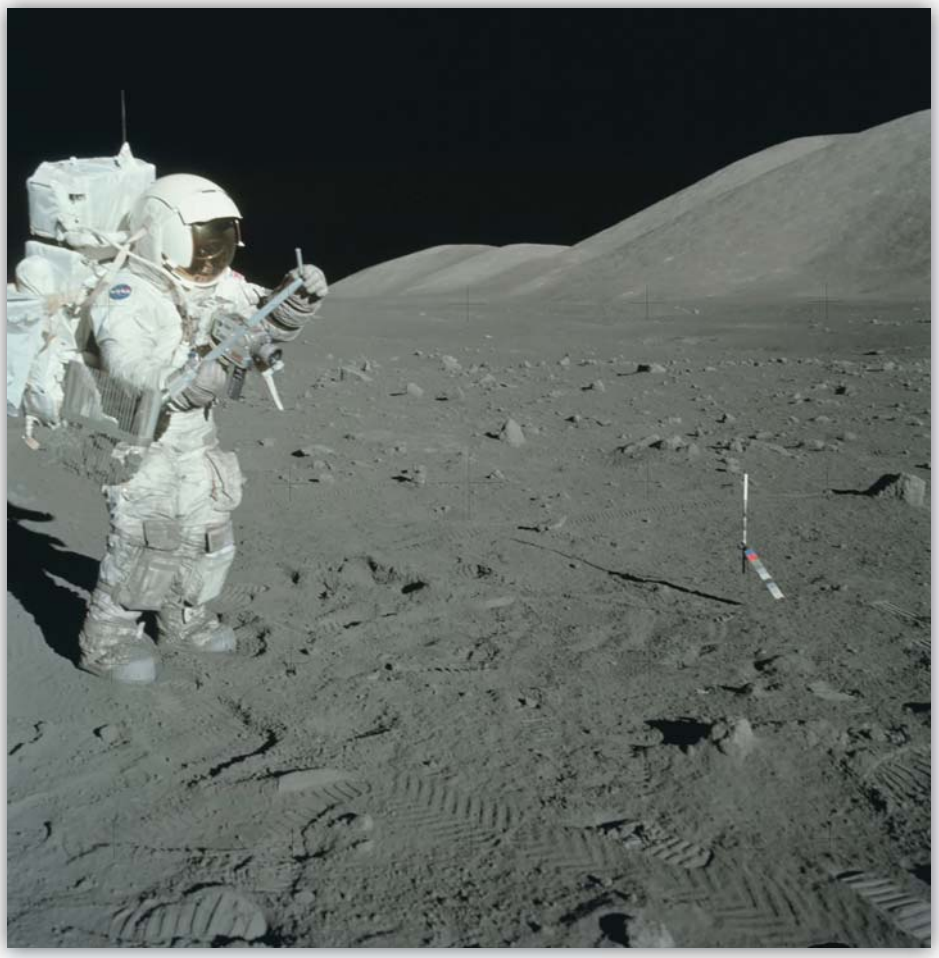


Figure 5.28-3. Photo AS17-134-20426 (Apollo 17).

from the flat backdrop used to simulate the lunar environment. The line, it is claimed, is revealed by sudden differences in color and sharpness.



Figure 5.28-4. A forced perspective backdrop in the movie Singin' in the Rain *(MGM). The corridor is actually a flat painting. Viewed from a different angle, the trick would be immediately evident.*

This claim, however, clashes with the fact that in many instances there are photographs taken from various viewpoints of the same lunar location. The movie trick of using backdrops (forced perspective) only works from a single viewpoint: viewed from a different location, the illusion of depth is destroyed.

The 16 mm film footage taken while riding the Lunar Rover shows changes in viewpoint that would be impossible on a movie set with backdrops and clearly reveals the rises and hollows of the terrain (Figure 5.28-5).



Figure 5.28-5. 16 mm film footage of the Lunar Rover in motion, taken during Apollo 16 [http://tiny.cc/j1xzbz].

The same kind of dividing line can be seen in real panoramic views taken on Earth, such as this image showing the desert in Kenya as shown in Figure 5.28-6.

In other words, the presence of dividing lines and sudden color difference is not necessarily evidence of the use of backdrops.

The explanation that best fits all the phenomena that can be observed in the photographs taken on the Moon is that the terrain is not uniformly flat but has rises and hollows, which naturally form dividing lines, for example along the ridge of a rise. Without familiar references (trees or houses, for example), and without the atmospheric attenuation that occurs on Earth, it's hard to interpret these two-dimensional photographs correctly and realize that there are many undulations in the ground (Figure 5.28-8).

Stereo photographs of the lunar landscape instead reveal the actual shape of the terrain very clearly (Figure 5.28-7 and -9).



Figure 5.28-6. Credit: Filiberto Strazzari.

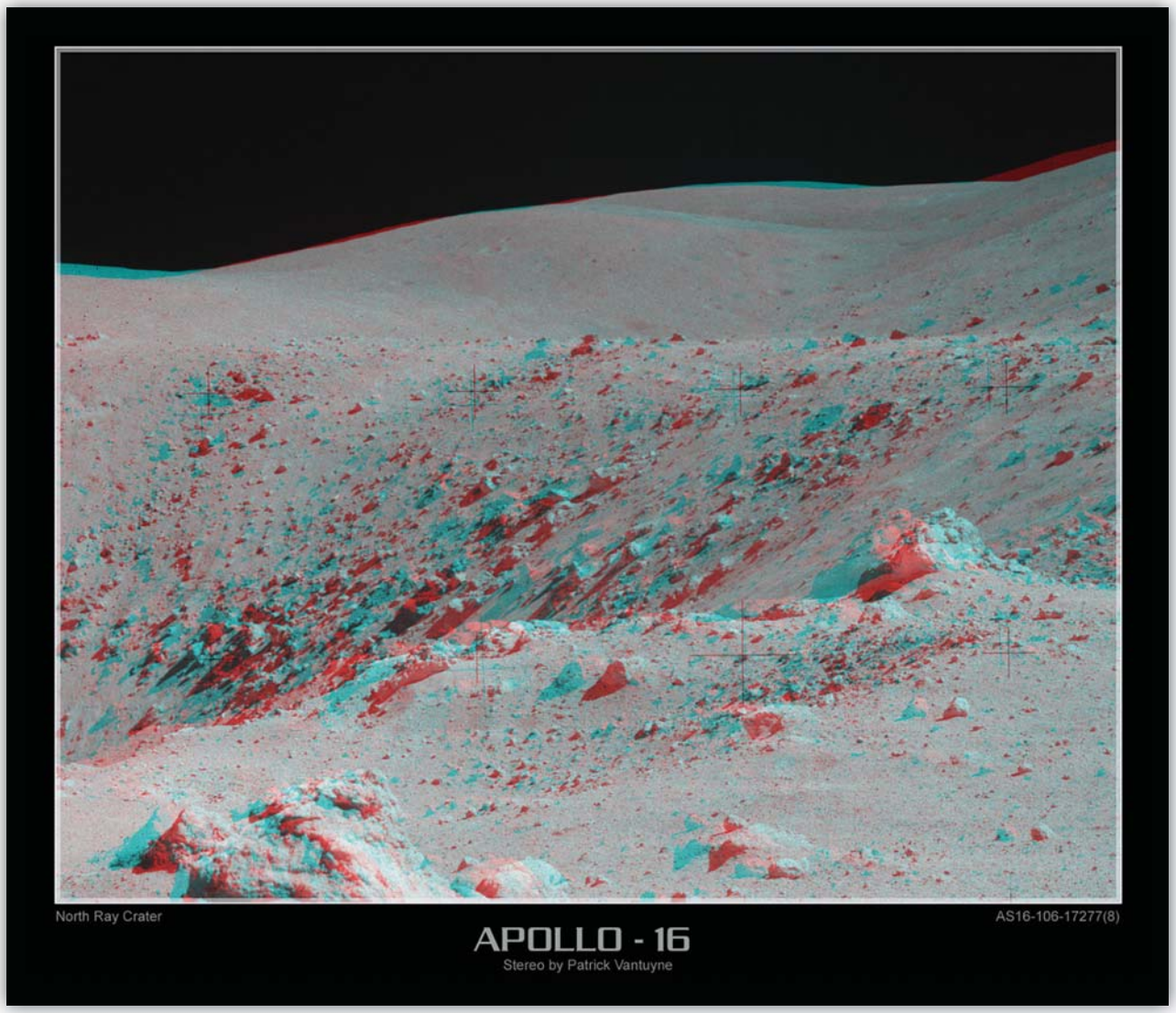
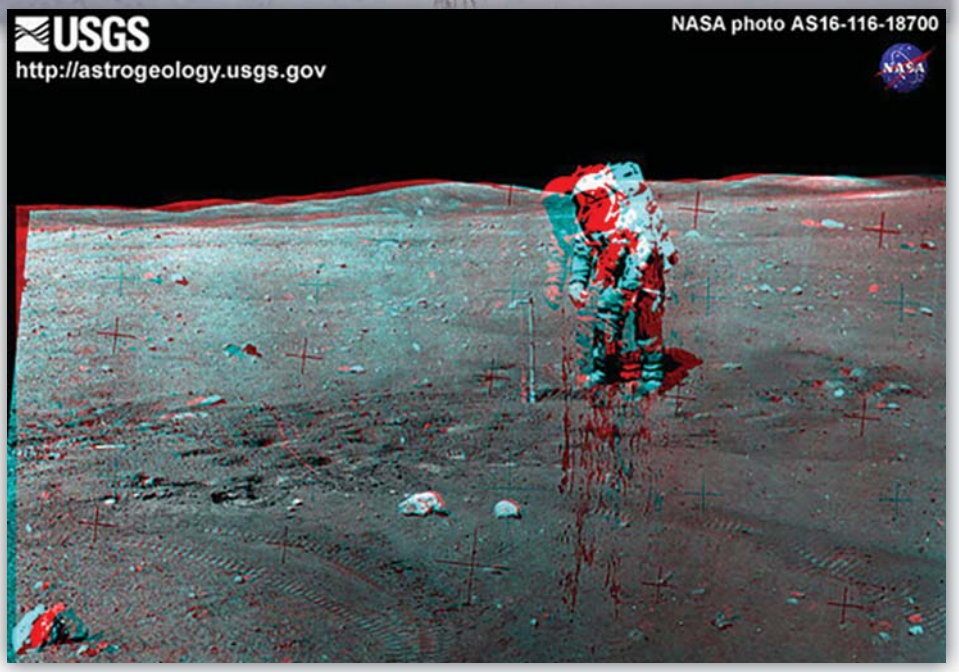


Figure 5.28-7. Stereo photograph created by Patrick Vantuyne by combining images AS16-106-17277 and 17278 (Apollo Anaglyph Galleries).



Above: Figure 5.28-8. Photo AS16-116-18700. Without depth clues, the terrain appears quite flat and uniform.



On the right: Figure 5.28-9. This stereo image obtained by combining photos AS16-116-18699 and 18700 (USGS Astrogeology Science Center) reveals the rises and hollows of the landscape.

5.29 Does this spacewalk photo show the reflection of the movie set in the astronaut's visor?

IN A NUTSHELL: *No. It's a photo from a ground test.*



Figure 5.29-1. An example of the allegedly fake photograph. Credit: Fake Astropix.

THE DETAILS: A photograph circulating on the Internet is described as an image of an astronaut spacewalk, taken during the Gemini 4 flight. But the photo shows a room reflected in the mirror-like visor (Figure 5.29-1). The caption of the photo says *"Hey NASA! Why is there an office reflected in your visor?"*.

However, the careful research of experts such as Ufoofinterest allow to find the original source of this photograph: it's a still from the footage of a ground test of the suit and of the jet-propelled maneuvering unit handled by astronaut White in preparation for his spacewalk in 1965.

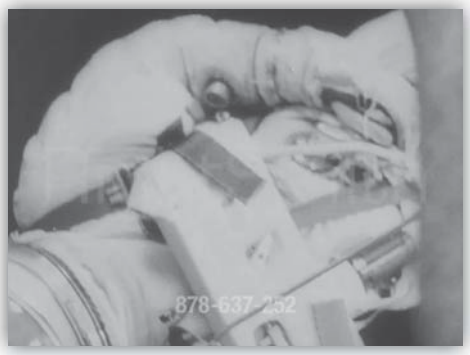


Figure 5.29-2. A still from the full footage shows a bare human arm entering the frame from the right.

The full film sequence is available for example at Framepool.com, where it is clearly identified as "*pre-flight test (for space walk)*". Moreover, the bare arm of a man can be seen in the sequence, revealing very clearly that this cannot have been filmed in the vacuum of space (Figure 5.29-2).

The specific frame used to create the image in dispute is shown in Figure 5.29-3.

Even without this patient search for the source of the image, common sense alone should make it obvious that NASA or any other government body who wanted to fake a spacewalk photograph would not have been so stupid as to leave the visor reflection in full view and hope that nobody would notice it.



Figure 5.29-3. The original movie frame used to create the disputed image. Credit: Ufoofinterest.

5.30 Why is there a fake photograph of Alan Shepard on the Moon?

IN A NUTSHELL: *Because it's a montage used originally in an autobiography of two astronauts, Deke Slayton and Alan Shepard, to illustrate Shepard's golf session on the Moon. No good footage of the event was available, so this reconstruction was used in the book. Unfortunately, it was not captioned to clarify that it was a montage. It is not included in NASA's official catalog of lunar photographs.*



Figure 5.30-1. Alan Shepard playing golf on the Moon in a photomontage.

THE DETAILS: The picture shown in Figure 5.30-1 appears to be a photograph of astronauts Alan Shepard and Ed Mitchell at a very special moment of their lunar excursion during Apollo 14: Shepard has attached a golf iron club head to the handle of a tool and is playing golf on the Moon, live on TV, using balls that he carried in his spacesuit pocket.

Shepard actually did play golf on the Moon, but this illustration of the event is fake.

This image appears in the autobiography written by Alan Shepard with his colleague Deke Slayton, *Moon Shot: The Inside Story of America's Race to the Moon* (1994), as documented by Figure 5.30-2.



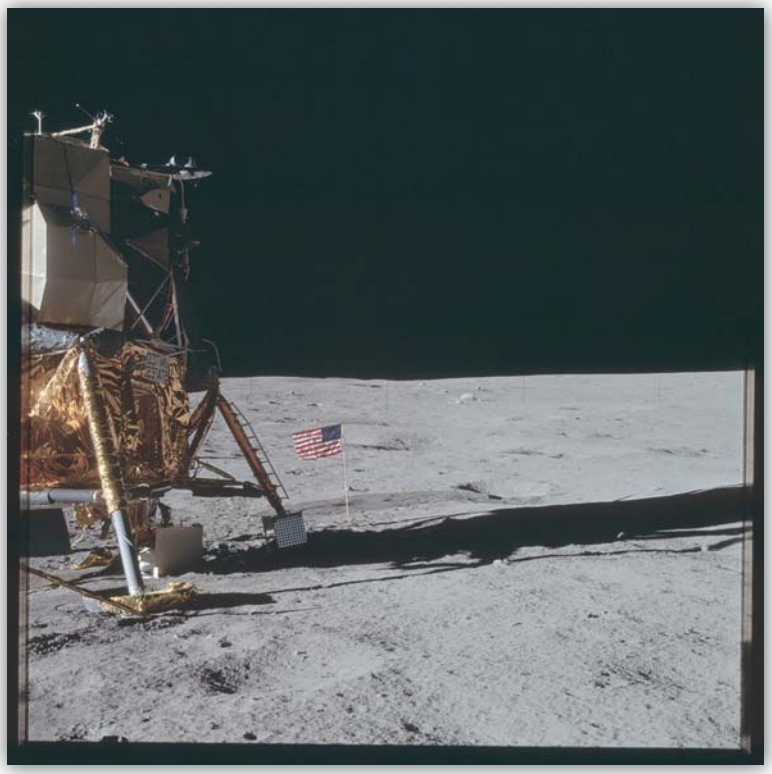
Figure 5.30-2. The undeclared montage in Moon Shot by Deke Slayton and Alan Shepard. Photo from the author's personal collection.

This picture is not an official NASA photo and is not in the catalogs of photos taken on the Moon. It is presumably the work of a somewhat unscrupulous publisher who wanted to illustrate this unusual moment but realized that there were no good pictures of it and therefore faked one without saying so.

The only real images of Alan Shepard's lunar golf session are in fact the ones taken from the live TV footage. Their quality is definitely not suitable for printing in a book (Figure 5.30-3).



Figure 5.30-3. A still from the TV broadcast of Shepard and Mitchell on the Moon as Shepard briefly plays golf.



On the right: Figure 5.30-4. Photo AS14-66-9276, flipped as in the montage.

Research by Fake Astropix has allowed to identify one of the real pictures used to create this montage: Apollo 14 lunar module photo AS14-66-9276, shown in Figure 5.30-4, was flipped to use it as a background. The original US flag of this photograph has been covered by a photograph of Mitchell, probably taken from photo AS14-66-9302 and likewise flipped. Shepard, the large parabolic antenna, some equipment were added, together with their shadows, and a white circle was placed in the sky, possibly to represent Earth.

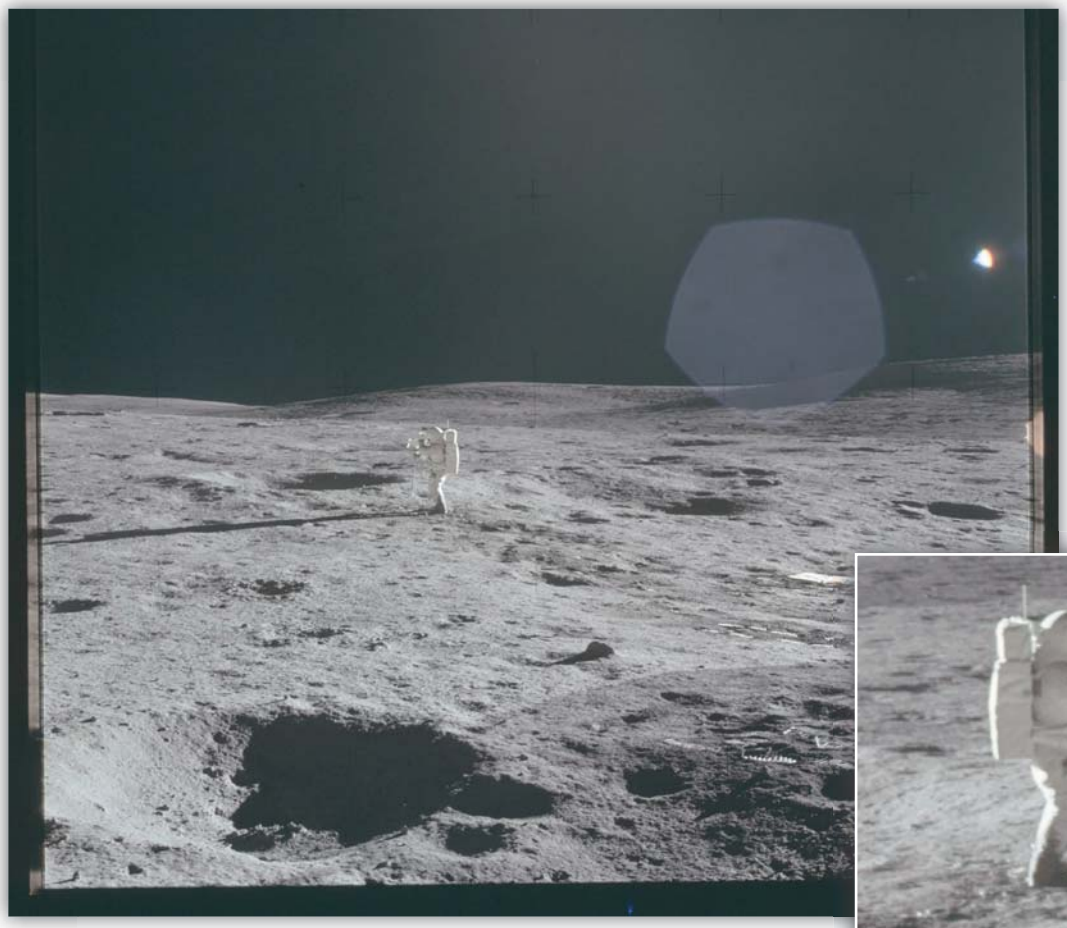


Figure 5.30-5. Photo AS14-66-9302, probably used to extract the image of Mitchell (cropped).

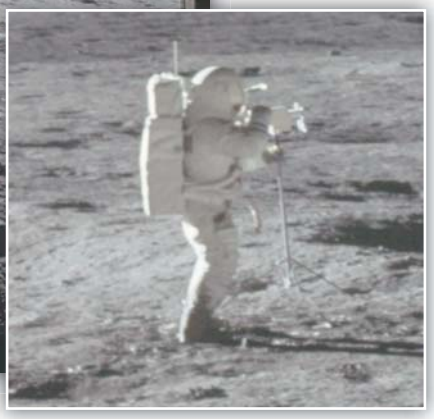


Figure 5.30-6. Detail of photo AS14-66-9302, probably used to add Mitchell to the montage.

5.31 Why is there a man in a waistcoat in a photo taken on the Moon?

IN A NUTSHELL: *It's not a man in a waistcoat: it's astronaut Harrison Schmitt, wearing a spacesuit. His image is distorted by being reflected in Gene Cernan's curved visor.*

THE DETAILS: It is claimed that one of the Apollo photographs shows a long-haired man in a waistcoat standing on what appears to be the surface of the Moon. This claim was reported by British tabloid *The Mirror* and by many other news sources in 2017.[5]

The Mirror reports this as a *"shock photo"* that *"appears to show a man walking around the 'moon' without a space suit during the US's Apollo 17 mission [...] [A] close-up analysis of one supposed image from the famous expedition that emerged this week suggests the whole enterprise was filmed on a Hollywood movie set."*

The source of this discovery is, according to *The Mirror*, a Youtube user known as *Streetcap1,* who reportedly claims that *"It looks like a man. Back in the early 70s. Long hair. Wearing some sort of waistcoat type thing."*

As always, one has to wonder why the hypothetical conspirators would be so colossally clumsy as to leave a picture of a man without a spacesuit in the Apollo photographs.

The detail of the alleged "man in a waistcoat" shown by the tabloid is in Figure 5.31-2.

The original Apollo 17 photograph from which this detail is taken is AS17-141-21608 (Figure 5.31-3). The *Apollo Lunar Surface Journal* and the NASA description of this photo report that it was taken at 165:17:01 of mission elapsed time, during the third EVA, by astronaut Harrison Schmitt and shows his crewmate Gene Cernan.

The alleged long-haired man can be glimpsed in the top left corner of the photograph, in the reflection

5 *US moon landing FAKED? Photo of astronaut's visor 'PROVES NASA staged Apollo 17 mission'*, by Jeff Farrell, *The Mirror*, 18 November 2017, archived at Archive.is and Archive.org; *Newsweek; Fox News; Maxim; IB Times; Newsline; Mirage News; Russia Today; Dunyanews Pakistan*.

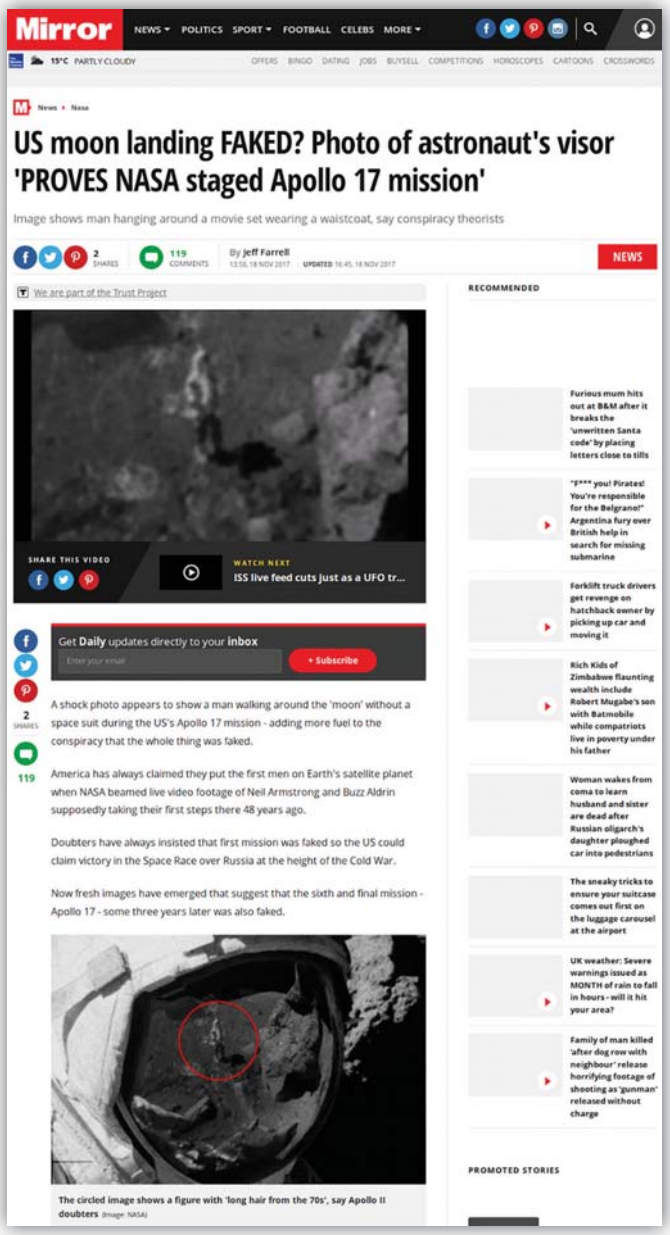


Figure 5.31-1. The "man in a waistcoat" report in The Mirror *(2017).*



Figure 5.31-2. The alleged "man in a waistcoat" in The Mirror *(2017).*

of Cernan's gold visor. It's a very small and blurry detail, even in the best scans available online (Figure 5.31-4, Flickr; Nasa.gov; Archive.org), so it takes quite a lot of imagination to see a *"waistcoat"* or *"long hair"*.

Comparing the *Mirror* and NASA versions of this detail reveals that the tabloid's picture has been processed to enhance its contrast, and this always produces digital artifacts, i.e., apparent details that didn't actually exist in the original subject.

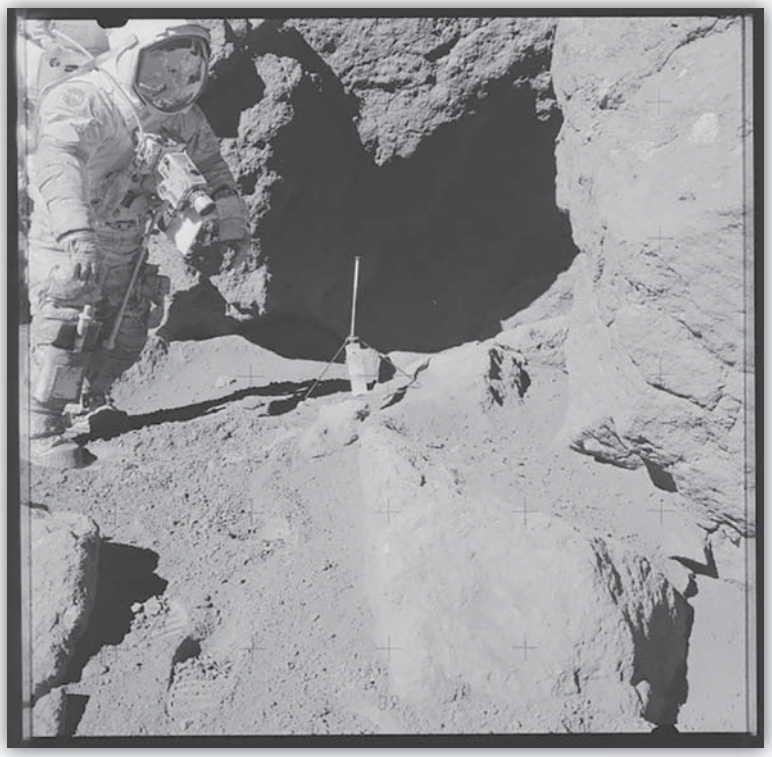


Figure 5.31-3. NASA photograph AS17-141-21608.

In the unprocessed NASA version, the person no longer appears to be wearing a waistcoat: the two dark bands on his body are, somewhat more plausibly, the shadow of his arm and of his upper body. The alleged long hair is simply the suit helmet.

The person's shadow, moreover, is too oddly shaped to belong to someone who is not wearing a spacesuit; its shape makes sense, however, if the person is wearing a large backpack, such as the portable life support system (PLSS) carried by Apollo astronauts.

There's another important detail: the person is reflected exactly in the part of the surface of the spherical visor that is at right angles to the observer, as can be seen in Figure 5.31-5.

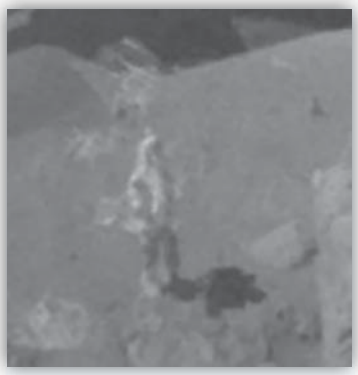


Figure 5.31-4. The "man in a waistcoat" in the best available scan of AS17-141-21608.



Figure 5.31-5. A detail of NASA photograph AS17-141-21608.

This is possible only if the person is taking the photograph. If you try to take a picture of a curved reflective surface, such as a road mirror or theft prevention mirror in a shop, you inevitably

end up being reflected in the region where the surface is perpendicular to you.

The most logical explanation, therefore, is that the person is simply Harrison Schmitt, the other astronaut who was on the Moon with Cernan and took the photograph.



Figure 5.31-6. A 2010 debunking of the "man in a waistcoat" claim.

Incidentally, this claim had already been made and debunked at least as far back as 2010 (Figure 5.31-6).

5.32 How come famous photographers claim that the Apollo photos are fake?

IN A NUTSHELL: *They're famous photographers, but they've always worked on Earth. They have no experience of photography in space, where lighting and lunar soil reflectivity are very different from Earth. Moreover, they were asked to judge digitally altered versions of the photographs instead of the original scans, which show none of the alleged inconsistencies. In one case they were even shown a fake (a montage) instead of a real Apollo photo and they didn't notice that it lacked the famous crosshairs that characterize all moonwalk photos.*

THE DETAILS: In his video *American Moon* (2018), Massimo Mazzucco argues in favor of several conspiracy theories by consulting experienced photographers: Toni Thorimbert, Aldo Fallai, Oliviero Toscani, Nicola Pecorini and Peter Lindbergh. Mazzucco himself is a photographer. These photographers set forth several technical objections that lead them to claim that the Apollo photographs are fake.

- **Radiation.** It is claimed that deep space radiation should have fogged the Apollo films. The photographers support this claim by noting that X-ray machines used in airports would fog their films unless they were shielded in lead containers. But this comparison is wrong, for the reasons already discussed in detail in Section 8.5: the intensity of radiation in space is nowhere near that of an X-ray scanner. It's like comparing a breeze and a hurricane. Besides, if radiation actually fogged films in deep space, then it should have fogged the films used in the uncrewed American and Russian probes that visited the Moon (Lunar Orbiter 1-5, 1966-67; Luna 3, 1959; Luna 12, 1966). It didn't.
- **Temperatures.** The photographers report their experience with extreme temperatures, noting that freezing cold or great heat would cause their cameras to jam due to thermal expansion and contraction and that their film would become brittle in deep cold. However, their experience is Earth-based. They are used to working in an atmosphere, which becomes cold or hot and conducts cold and heat by contact; this does not happen in the vacuum of space, as described in detail in Section 8.6. Once again, if this claim were true, then the cameras would have jammed and the films would have become brittle in the already mentioned Russian and American uncrewed lunar probes as well. They didn't.
- **Non-parallel shadows.** This claim has already been discussed in Section 5.6; the photographers, probably because they're not familiar with the lunar environment, don't appear to consider the possibility that the surface

of the Moon might have hollows or rises that alter the apparent direction of shadows.

- **Backlighting.** The photographers claim that astronauts and spacecraft photographed in shadow or with backlighting on the Moon should be completely dark. This objection, too, has already been analyzed in Section 5.18 and Section 5.5: in vacuum and in air, backlighting works in the same way and shadows receive light reflected off nearby sunlit surfaces.
- **Hotspots and fall-offs.** As already discussed in Section 5.17, the unusual nature of lunar soils tends to produce a brighter glow in the central region of a photograph. This happens in photos taken on the Moon by Chinese probes as well. Moreover, the exhaust of the landing rocket blasts away the surface dust in the areas it strikes, changing the reflectivity of the ground. These photographers are not familiar with lunar geology and with the details of the Apollo missions; they are unaware of these peculiarities and accordingly try to explain them by referring to the studio lighting techniques that they know, speculating that NASA used a spotlight that was able to cover only the central region of the ground. They don't stop to ask themselves why NASA should have been so penny-pinching as to use an inadequate spotlight instead of a more powerful one that would light up everything well and evenly from a distance.

In summary, these well-known photographers are experts in *terrestrial* photography and their artistic and technical talent is undisputed *on Earth*. But they have no experience in space and they are not familiar with the unusual characteristics of the space environment (such as a black sky in full daylight on the Moon, with no light scattered by the atmosphere as occurs on Earth). Accordingly, it is understandable that they reach wrong conclusions.

Their mistake is even more understandable if they are given heavily processed photographs or even fakes. The pictures shown to them by Mazzucco in fact have an artificially exaggerated contrast, and one of them is a montage.

For example, Mazzucco shows them the well-known photograph shown in Figure 5.32-1, and they reply that it must be false because of the fall-off of light in the foreground and background.



Figure 5.32-1. Photo AS11-40-5903 in the version shown by American Moon*.*

However, this version has a much higher contrast than the original scan, and this exaggerates the small differences in ground brightness. The alleged hotspots and fall-offs

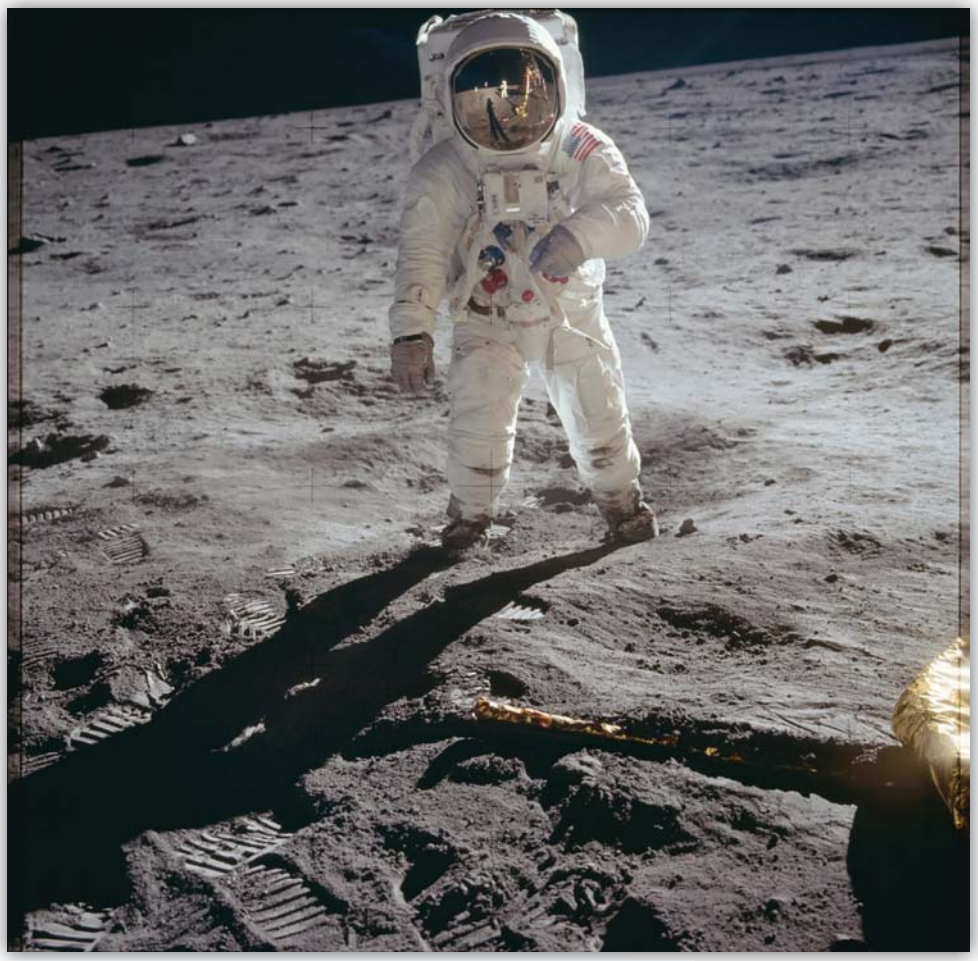


Figure 5.32-2. Photo AS11-40-5903, processed for higher contrast and more solid blacks.

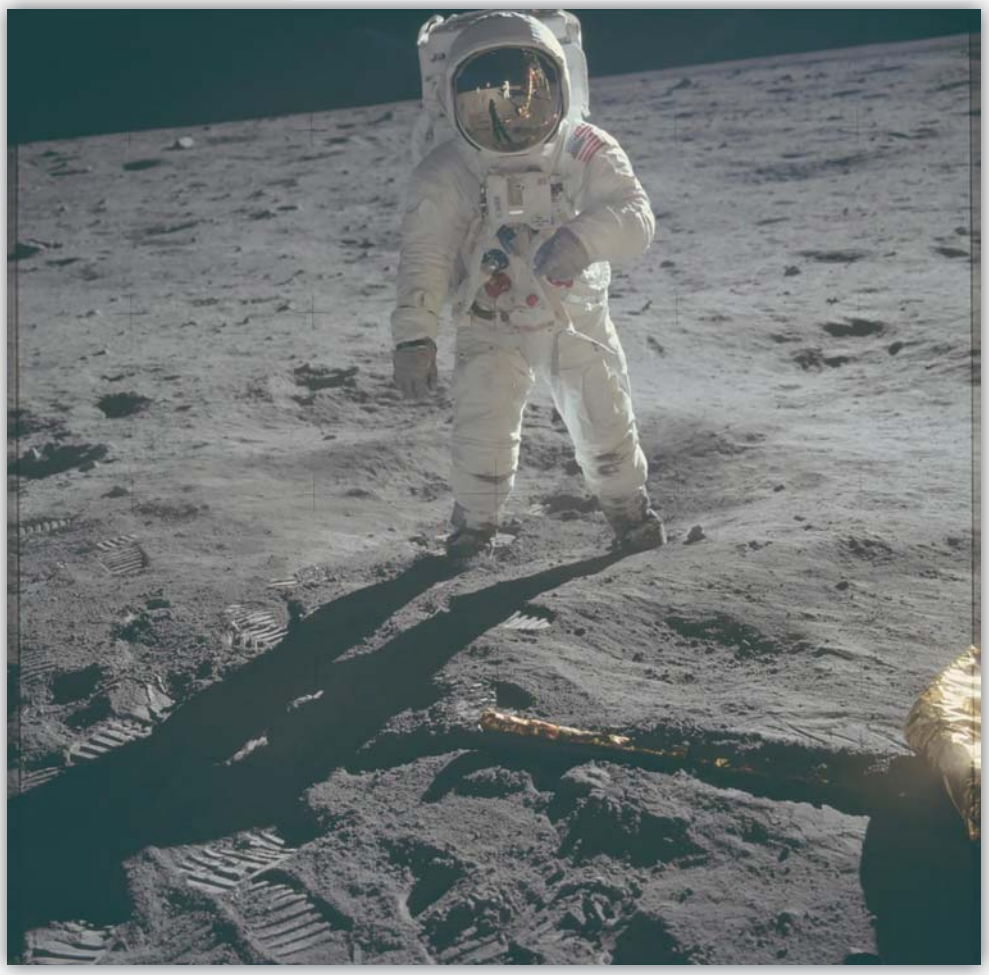


Figure 5.32-3. Unprocessed scan of photo AS11-40-5903.

are essentially digital artifacts.

Contrast exaggeration is often used for aesthetic purposes, as shown by Figure 5.32-2 (which is not as exaggerated in contrast as the version used by Mazzucco); the actual brightness variations are very small, as shown by the unprocessed scan of Figure 5.32-3.

The full set of Apollo 11 EVA photographs is available online in processed and unprocessed form.



Figure 5.32-4. Toni Thorimbert criticizes a photograph in American Moon*.*

There's more. Mazzucco asks Thorimbert, Toscani, Fallai and Lindbergh to examine the picture shown in Figure 5.32-4 and they reply that it's fake because of its inconsistent lighting.

None of these expert photographers, however, realize that this is not an actual Apollo photograph: it's a montage (Figure 5.32-5), already discussed in Section 5.27. None of these experts notice obvious clues, such as the lack of crosshairs and the fact that the Sun has been added digitally with typical computer graphics effects (a 1960s camera would never produce such circular lens flares).



Figure 5.32-5. A montage created in 2008 by Ed Hengeveld.

Even more importantly, this montage was created by combining photographs taken with different settings for the areas in shadow areas and for the areas in full sunlight, and therefore creates a misleading perception of the lighting conditions that the photographers have been asked to assess.

In other words, Massimo Mazzucco asked the photographers whether the lunar photographs are false by giving them a false photo to examine. Their answer is not surprising.

6 Alleged video and film anomalies

Supporters of Moon fakery theories believe that they have found evidence to back up their allegations not only in the photographic record, as discussed in the previous chapter, but also in alleged anomalies in the live TV broadcasts from space and from the Moon and in the film footage of the Apollo missions.

Understanding the real reasons for these purported anomalies requires a little knowledge of 1960s television and film technology. Therefore, this chapter begins with a quick primer on this topic and then moves on to discuss and explain the main video and film footage anomalies that can easily lead a non-expert observer to question their authenticity.

6.1 Apollo video and movie technology: a quick primer

The Apollo visual record includes both video recordings, made using TV cameras that transmitted their pictures to Earth, where they were rebroadcast and recorded on magnetic tape, and film footage, shot using movie cameras that recorded the pictures onboard on 16 mm film.

Today it's quite commonplace to use the term *video* for any kind of moving picture, lumping together TV and film, but in the Sixties there was a huge quality and portability gap between television and movie technology.

The miniaturization afforded by modern electronics was in its infancy. Studio TV cameras for color broadcasts were bulky, inefficient, power-hungry monsters that weighed over 125 kilograms (280 pounds), like the ones shown in Figure 6.1-1.



Figure 6.1-1. RCA TK-43 color TV cameras in the 1960s. Credit: Oldradio.com.

Early "portable" color TV cameras, such as the Ikegami HL-33, made their debut only in the Seventies. Black-and-white models were slightly less unwieldy, but they were still massive, power-hungry, heavy devices that could not be used in low light and depended on an external electric power supply and on even bulkier recording equipment. Moreover, they provided rather poor picture quality: nothing even comparable to today's tiny high-definition video cameras and recorders that we carry in our pockets as part of our cellphones.

Movie cameras, instead, were already a mature technology. They were compact, lightweight, sturdy and fully independent of mains power thanks to batteries or wind-up mechanisms. Movie cameras for amateur use were just a little bit bigger than a still camera.

For example, a professional Arriflex movie camera using 16 mm film weighed about six kilograms (13 pounds) and required no extra equipment, apart from an optional sound recorder and a good supply of film, to shoot anywhere in the world, taking moving color pictures with a quality that far surpassed that of television. A professional movie camera was, in a way, the 1960s equivalent of today's portable high-definition video gear.

Movie cameras were used for virtually all news footage, for war zone reporting and for detailing science experiments, missile launches and aircraft tests, thanks also to the in-depth analysis offered by *slow motion*, which was easy to achieve with film but technically unattainable with the TV cameras of the day (the film was simply fed through the camera at a faster rate and then shown at the normal rate).

The key drawbacks of movie cameras were of course the recording time, which was limited by the amount of film available, and the impossibility of live broadcasts, since film had to be developed by a chemical process. But if live transmission was not indispensable and a deferred viewing was acceptable, in the Sixties film was king. It's important to bear this in mind in order to understand the technical choices made by NASA in documenting the Apollo flights.

The Apollo movie cameras

The Apollo lunar missions carried so-called *Data Acquisition Cameras* (DAC), movie cameras that used 16 mm color film magazines (Figure 6.1-2).



Figure 6.1-2. The Maurer 16 mm movie camera used in the command module of Apollo 11. Credit: Smithsonian National Air and Space Museum.

They were extremely compact and lightweight: including the side-mounted magazine, they measured approximately 22 x 13 x 6.5 centimeters (8 3/4 x 5 x 2 1/2 inches) and weighed 1300 grams (2.9 pounds).

One of these movie cameras was mounted in the Lunar Module so as to look downward out the right side window of the spacecraft, as shown in photograph AS11-36-5389 (Figure 6.1-3). This simple

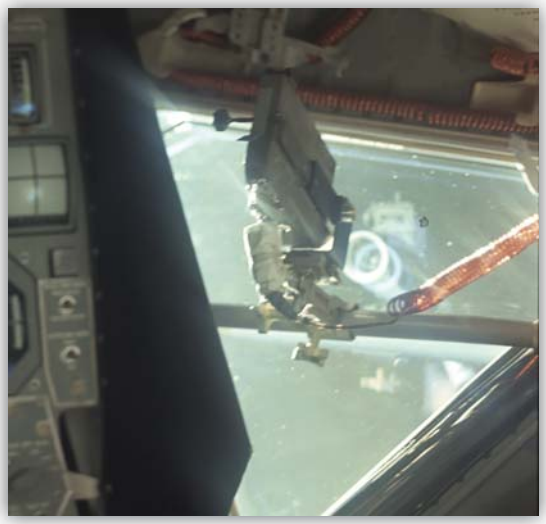


Figure 6.1-3. The Maurer movie camera in position before Apollo 11's Moon landing. Detail from photo AS11-36-5389.

but effective technology is what gave us color pictures of the lunar module's descent to the Moon and of Neil Armstrong's first footstep on the lunar surface.

Most of mankind's first moonwalk (86 minutes out of 131) was filmed in color with this system. The first few minutes used a rate of 12 frames per second, half that of a normal movie; the remainder of the excursion was shot at one frame per second in order to save film, since each film magazine only contained 39.6 meters (130 feet) of color film, which at a normal frame rate (24 frames per second) would have been enough to shoot a little more than three and a half minutes. Reducing the frame rate increases the recording time but produces jerkier moving pictures. At one frame per second, the film footage is more like a series of still photographs than an actual moving picture record.



Figure 6.1-4. Top left: the movie camera mounted on the Rover, next to Charlie Duke, during training for Apollo 16.

In later missions, after Apollo 11, the movie camera was taken outside, on the lunar surface. For Apollo 12 it was placed on the Lunar Hand Tool Carrier (a frame with legs); on Apollo 14 it was installed on the Modularized Equipment Transporter, a sort of wheeled cart; for Apollo 15, 16 and 17 it was mounted on the Lunar Rover (Figure 6.1-4, which shows how truly small the camera was).

All this footage is now available at medium resolution on the Internet and in high resolution on the DVDs and Blu-rays published by specialist firms such as SpacecraftFilms.com.

The Apollo TV cameras

Transmitting television pictures from space and from the Moon entailed two technological challenges that had never been met before.

The first one was to build a TV camera that could work in a vacuum, withstand great brightness and temperature variations between shadow and sunlight and survive the intense vibration and acceleration of liftoff, yet be compact and lightweight enough to allow an astronaut to carry it and operate it in the confined space of the interior of a spacecraft and on the lunar surface.

The other challenge was to find a way to send back to Earth a live television signal from a distance of almost 400,000 kilometers (250,000 miles) using only the electric power available on board the Apollo craft and the vehicle's radio transmission equipment, which had been designed for entirely different purposes. Live TV from the Moon was, in a way, an afterthought.

Apollo 7 and Apollo 8 carried a single black-and-white slow-scan TV camera made by RCA. With Apollo 9, NASA tested and used a black-and-white TV camera built by Westinghouse intended for later use on the Moon. Apollo 10 introduced a Westinghouse color TV camera, qualified only for inflight use. Apollo 11 carried a color camera for onboard use and a black-and-white camera for use on the Moon.

The Westinghouse Lunar Camera used on Apollo 11 (shown on the left in Figure 6.1-5) used only 6.5 watts, measured 28 x 15 x 7.6 centimeters (11 by 6 x 3 inches) and weighed 3.3 kilograms (7.25 pounds), yet was capable of working in the harsh environment of the Moon, with its vacuum and its temperature extremes. This remarkable performance, miniaturization and weight reduction were achieved by using 43 integrated circuits, which were very rare in those days, and a special component, an *SEC* (*Secondary Electron Conduction*) *tube*, which at the time was a military secret.



Figure 6.1-5. Stan Lebar, head of Westinghouse's Apollo TV camera project, shows the onboard camera (left) and the lunar camera (right) for Apollo 11.

This achievement, however, came initially at the cost of color. That's why the TV pictures of the first Moon landing are in black and white.

As technology progressed and NASA's confidence in being able to receive a complex TV signal from the Moon improved, subsequent missions were provided with a slightly larger color lunar camera, which produced color by using the same clever method used by the onboard camera: a *color wheel* (a disk with colored filters) spun in front of the monochrome camera sensor, generating a set of three color-filtered pictures, which were reassembled by the ground stations on Earth to recreate the original colors. This was a very compact and reliable system, although it caused multicolor halos around rapidly moving objects.

Having solved the issues of weight and size, there was still the question of sending the camera's signal to Earth. The limitations of the Lunar Module's onboard transmission equipment allowed a *bandwidth* of only 700 kHz, whereas a standard TV signal required 6,000. This meant that the



Figure 6.1-6. The converted image as broadcast by world television networks during the first steps on the Moon of Apollo 11.



Figure 6.1-7. The original image as received from the Moon, photographed from the monitor prior to conversion.

standard US TV format (NTSC) had to be abandoned and a custom one, with a lower quality, had to be used. For Apollo 11, this format had 320 progressive lines and 10 frames per second, compared with 525 interlaced lines and 30 frames per second of an ordinary US TV broadcast. The lunar TV camera also had a "high definition" mode that generated a 1,280-line picture every second and a half, but it was never used.

These nonstandard solutions required special equipment on Earth to convert the signal to the normal television format. Since there was no digital technology capable of real-time video processing in the 1960s, a rather drastic approach was taken: a standard broadcast television camera was pointed at a special high-persistence monitor that displayed the images from the Moon.

The loss of detail and quality caused by this conversion was partly compensated by electronic devices, but nevertheless the difference between the signal that was received from the Moon and the converted signal was great (Figures 6.1-6 and 6.1-7).

The Apollo 12 and 14 moonwalks used a color TV camera that had a lower resolution (262 lines) but a higher frame rate (30 filtered frames per second, which became 20 frames after combining them to recreate the colors) than the Apollo 11 camera.

The Apollo 15, 16 and 17 missions were provided with a different, bigger TV camera, the *Ground Commanded Television Assembly* (GCTA) manufactured by RCA, which was mounted on the Lunar Rover electric car and was controlled directly from Earth. This TV camera had a 6x zoom lens and a resolution of approximately 200 lines. Like the previous model, it generated 30 frames per second, which became 20 after conversion.

The two final lunar flights, Apollo 16 and 17, also introduced more advanced image processing systems that reduced background noise and improved considerably the quality of the color transmissions.

This processing was handled by a private company, Image Transform of North Hollywood, California, which received the pictures from the Moon for on-the-fly processing before sending them to the world's TV networks for live broadcast. In a way, therefore, it's true that some live TV footage from the Moon was created with help from Hollywood.

Incidentally, Image Transform was founded by John Lowry, who later also created the Lowry Digital company that restored the Apollo 11 lunar TV broadcast in 2009.

During Apollo 11's moonwalk, the TV signal was received by huge 64-meter (210-ft) dish antennas at Goldstone, California (Figure 6.1-8) and at Parkes, Australia and by a 26-meter (85-ft) dish at Honeysuckle Creek, Australia. Apollo 11's liftoff from the Moon was tracked by the 26-meter (85-ft) dish at Fresnedillas, near Madrid, in Spain, which was also used to receive the live TV broadcasts made by later flights.



Figure 6.1-8. The Goldstone dish antenna in the 1960s. The cars reveal the size of this receiving apparatus.

All the television broadcasts, including the restored Apollo 11 moonwalk, are now available on the Internet and on DVD, and so is the movie camera footage of the missions.

Now that the key aspects of the video and film technology available to lunar astronauts in the 1960s have been outlined, we're ready to examine the various anomalies allegedly present in the television and movie camera records of the Apollo missions.

6.2 Why does the flag flutter on the airless Moon?

IN A NUTSHELL: *It's not fluttering: it's* swinging*, and it only does so when the astronauts handle it or touch it, or when it is struck by the blast of the lunar module's maneuvering rockets or by the air vented from the hatch. Moreover, the way it swings is different from how a flag swings on Earth and actually proves that the footage had to be shot in a vacuum.*

THE DETAILS: In the TV and film footage of the lunar landings, the American flag sometimes moves as if it had been blown by a sudden gust of air. That, it is argued, is impossible on the airless Moon; therefore, according to conspiracy theorists, this proves that the moonwalk footage was faked in a movie studio.

One might ask why the movie set used for the most important and complex fakery of the twentieth century would be so ridiculously shoddy as to have drafts, or why the people in charge of the hoax would be so pathetically dumb as to leave such glaring and revealing mistakes in the final product, but never mind. There's a simple and rather interesting explanation for the apparently strange behavior of the flag.

If you examine the Apollo footage, you find that when the flag "flutters" it continues to oscillate stiffly and unnaturally for quite a while, differently from a flag on Earth, which changes shape and comes to a standstill almost immediately. This unusual and persistent oscillation is possible because the flag is moving in an airless environment, without encountering any air resistance. If you compare the Apollo videos with footage of a flag moving on Earth, the difference in behavior is very obvious.

In 2008 the TV show *Mythbusters* put this to the test. An accurate replica of an Apollo flag was placed in a large vacuum chamber and its pole was turned, just like the astronauts did on the Moon. The same turning motion was applied while the chamber was filled with air and after the air had been extracted to produce a vacuum. The difference was quite evident: when the flag was in vacuum, it swung for much longer and in the drag-free way seen in the Apollo television record.



Figure 6.2-1. A flag is swung in a vacuum for Mythbusters *(2008) [http://tiny.cc/tp7idz].*

In other words, the anomalous motion of the lunar flags doesn't confirm the hoax theories: on the contrary, it

confirms that the footage of the moonwalks was shot in a vacuum.

Careful examination of the lunar footage, cross-checking it with mission timelines, also shows that the flag "waves" only in very specific circumstances.

For example, the flag moves when an astronaut turns its pole to drive it into the ground (Figure 6.2-2). After the flag has been erected and left to settle, it doesn't move. Even its creases and wrinkles remain unchanged throughout the excursion, as discussed in Section 5.3 for the Apollo 11 flag.



Figure 6.2-2. Flag oscillation in an Apollo TV transmission while an astronaut drives its pole into the soil.

The Apollo 14 "flutter"

In the video footage of Apollo 14, the flag oscillates repeatedly, entering the frame and exiting it, without being touched by anyone. At this point in the mission timeline, the astronauts are inside the lunar module.



Figure 6.2-3. Flag oscillations in the video Moon Hoax Now 2017: Apollo 14 - Hidden Flag *(2017) [http://tiny.cc/gs7idz].*

The technical explanation suggested for this slight motion is the gradual venting of the lunar module cabin air. The flutter in fact occurs while the astronauts are getting ready for their second moonwalk and this means that they have to vent all the air inside the cabin. This venting occurred through a valve located on the lunar module hatch, which faces the flag.

Such venting of a large volume of air into a vacuum, therefore without the pressure and resistance of an atmosphere, would create a swiftly expanding cloud of air, which would strike the flag gently but with enough force to make it swing, especially since the flag is not hindered by air resistance. It would have a nonzero pressure on one side and zero pressure on the opposite side, so some motion would be inevitable.

The Apollo 15 "flutter"

There's a moment in the Apollo 15 footage, at 148:57:15 in mission elapsed time, in which the flag swings stiffly, with the typical oscillation that occurs in a vacuum, although apparently it has not been touched by



Figure 6.2-4. Flag oscillations (at 2:36) in the video Apollo 15 flag waving *(2007) [http://tiny.cc/3t7idz].*

astronaut Dave Scott as he passes in front of it (Figure 6.2-4).

At first glance, it does indeed look as if Scott's movement displaced some air which impinged on the flag. But before arguing that this is unquestionable evidence of fakery, other non-conspiratorial explanations should be considered. Experts have been intrigued by this phenomenon and have discussed it at length in the *Apollo Lunar Surface Journal* (*EVA-2 Closeout*, at 148:57:15).



Figure 6.2-5. Discussion of the Apollo 15 flag motion from the video Apollo 15 moving flag analysis *(2010) [http://tiny.cc/rw7idz].*

For example, the apparently mysterious motion may have been due to actual contact between Scott's left arm and the flag. Due to the wide-angle setting of the camera lens, which exaggerates depth, Scott appears to be farther away from the flag than he actually is. This would explain the fact that only the lower portion of the flag moves (Figure 6.2-5).

Another possible explanation is an electrostatic effect. As Scott walked on the lunar surface (which has a significant electrical charge of its own due to the ionizing effect of ultraviolet radiation and particles from the Sun), he may have accumulated a charge which attracted or repelled the flag in the same way that a plastic rod rubbed on a wool sweater attracts or repels hair or pieces of paper.

Since the almost-perfect vacuum close to the lunar surface is highly *dielectric* (i.e., essentially incapable of conducting electric currents), charge accumulation is easier than on Earth. Moreover, any attraction or repulsion of the flag is more conspicuous on the Moon than on Earth because on the Moon there's no air to slow the flag.

Another conceivable scenario is that the discharge from the astronaut's backpack sublimator might have created a momentary puff of gas that impinged on the flag. This would explain the fact that only the bottom corner of the flag moves.

Whatever the actual cause is, it can't be an air displacement on a movie set, because the same video sequence shows that the dust kicked by the astronaut's boots doesn't swirl, but falls sharply and neatly in an arc. This is typical of a vacuum and is not possible in air. The flag's slow and long-lasting oscillation is also consistent with a low-gravity vacuum environment.

6.3 Who was already outside to televise Armstrong's first steps?

IN A NUTSHELL: *Nobody. There was an automatic TV camera attached to the outside of the lunar module.*

THE DETAILS: Some doubters ask how the TV footage of Neil Armstrong's first steps on the Moon was shot from ground level outside the spacecraft if nobody was on the Moon yet to hold the camera.

The answer can be found in the technical documentation of the Apollo missions, which shows that the TV camera was located on the outside of the lunar module. The wide-angle lens of the camera gives the impression that the viewpoint was far away, but the camera was actually quite close to the descent ladder.



Figure 6.3-1. A training mock-up of the Lunar Module shows the tilt-down MESA container in the deployed position, to the left of the ladder. The arrow indicates the TV camera, which is in the position for broadcasting the descent along the ladder.

One of the sides of the octagonal structure of the lunar module descent stage supported a tilt-down container known as *Modular Equipment Storage Assembly* or *MESA* (Figure 6.3-1), which was used to store the various instruments and tools that the astronauts would use during their moonwalks. This container also supported the TV camera (Figure 6.3-2), which was mounted on a bracket and was already connected to the power supply and to the onboard transmission equipment. The placement of the camera had been preplanned and rehearsed for the very purpose of documenting this historic moment. No external TV operator was required.

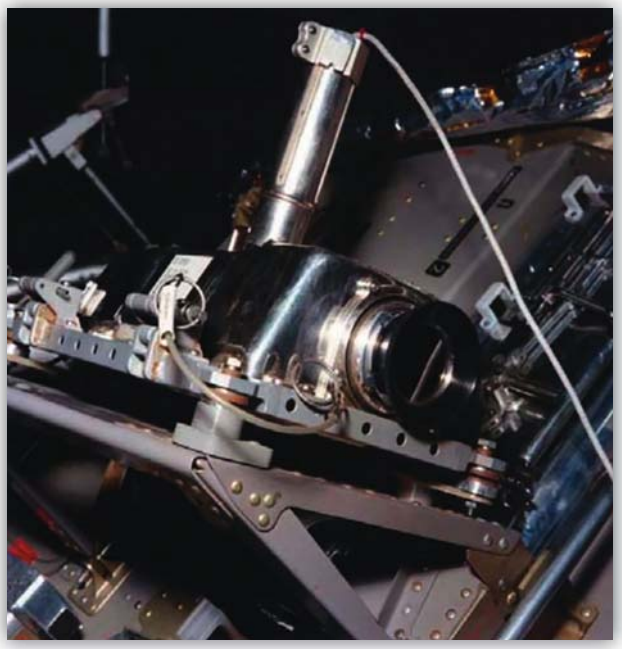


Figure 6.3-2. Apollo 11's lunar TV camera, upside down on its bracket inside the MESA.

During the Apollo 11 mission, Neil Armstrong, the first astronaut to exit from the LM, pulled a cable while he was still at the top of the ladder. This cable released this container and allowed it to open by tilting downward. This automatically positioned the black-and-white TV camera. Its supporting bracket was not perfectly horizontal: that's why



Figure 6.3-3. A TV picture of Neil Armstrong on the Moon during Apollo 11, straightened to correct the tilt of the camera mounted on the outside of the lunar module. Photograph taken by Ed von Renouard by pointing a film camera directly at the monitor that displayed the images from the Moon at Honeysuckle Creek, in Australia.

the TV picture of Armstrong's first steps is tilted (Figure 6.3-3).

The same camera was then removed from its receptacle, installed on a tripod and placed at a certain distance from the LM, to which it was connected by means of a cable, so as to televise the entire Apollo 11 moonwalk.

A similar solution was used for Apollo 12; however, the TV camera (a color version this time) was pointed at the Sun by mistake shortly after the beginning of the first moonwalk (at 51:30 in Figure 6.3-4). The intense sunlight damaged its sensor, putting an abrupt end to live television from the Moon for the remainder of that mission.

The camera was installed upside down in its MESA receptacle and therefore the pictures of the astronauts' descents along the ladder were transmitted from the Moon upside down. Technicians on Earth would flip the image to broadcast it right way up, but at the very beginning of the Apollo 11 lunar TV transmission they momentarily forgot this task and so the first seconds of the broadcast are upside down.



Figure 6.3-4. The TV broadcast of the Apollo 12 moonwalk.

A similar mishap occurred during Apollo 12: the TV signal was flipped correctly to show Pete Conrad's descent, but when he turned the camera right way up to mount it on the tripod (at 37:00 in Figure 6.3-4) the image remained flipped and therefore showed Alan Bean's descent upside down.

6.4 Who stayed behind to shoot the liftoff from the Moon?

IN A NUTSHELL: *Nobody. The footage of the liftoff of the Lunar Module from the Moon was shot using an independently powered TV camera that was radio controlled from Earth.*

THE DETAILS: The visual record of the Apollo missions includes footage of the liftoff of the Lunar Module from the Moon. Some conspiracy theorists and doubters argue that this video must be fake, since there was nobody left on the Moon to take the pictures and even move the camera to follow the ascent stage of the Lunar Module as it climbed into the sky.



Figure 6.4-1. The live color TV footage of Apollo 17's liftoff from the Moon: the ascent stage of the Lunar Module separates from the descent stage and its rocket motor exhaust propels fragments of the thermal protection of the descent stage [http://tiny.cc/697idz].

The answer is simple, if you take the time to read the technical documents of the Apollo missions: the lunar liftoff was shot only during Apollo 15, 16 and 17, when the TV camera was installed on the Rover (the astronauts' electric car), which at the end of the excursion was parked approximately 90 meters (300 feet) east of the Lunar Module for the very purpose of recording the liftoff of the LM.



Figure 6.4-2. Graphic reconstruction of how the LM liftoff videos were shot. From the documentary Live from the Moon *(Spacecraft Films).*

The camera equipment was powered by the batteries of the Rover and was controlled remotely by an operator on Earth through a radio link. Indeed, its technical name was *GCTA*, which stands for *Ground Controlled Television Assembly*.

The signal from the TV camera left on the Moon was transmitted directly to Earth through the parabolic antenna installed on the Rover, using the same method used to transmit the astronauts' moonwalks. At the time, video recording equipment was very bulky and heavy and therefore the lunar camera was not equipped to record. The liftoff had to be relayed to Earth live. Moreover, the shot had to be carefully planned beforehand.

The radio control signals in fact took about two seconds to travel from the control center in Houston to the transmitters located at various sites on Earth and from there to the Moon at the speed of light. This two-second delay made it impossible to correct the camera movements in real time: any command would reach the camera too late. Accordingly, NASA had to calculate in advance a very precise placement of the TV camera and send all commands two seconds earlier

in order to have the camera tilt up and follow the ascending lunar module at the right time.



Figure 6.4-3. Ed Fendell, the remote-controlled TV camera operator, explains the details of how the liftoff shots were achieved [http://tiny.cc/yd8idz].

For the Apollo 15 liftoff, the camera did not tilt to follow the spacecraft, due to a malfunction of one of its motors. For Apollo 16, the camera operator, Ed Fendell, tried to follow the ascent, but was unable to do so because the Rover had not been placed correctly by the astronauts at the exact preplanned distance required to achieve the shot.

The Apollo 17 liftoff shot was achieved almost perfectly and managed to keep the spacecraft in frame as it departed.

Incidentally, since the entire system was powered independently by batteries, it was able to transmit even after the astronauts had left the Moon, sending back lonely images of the moonscape, once again devoid of life and motion after humankind's brief visit.

6.5 Were the astronauts lifted by wires when they fell?

IN A NUTSHELL: *No. Their movements on the Moon seem odd because they weighed less than 30 kilograms (66 pounds) including their suit, and their spacesuit and backpack displaced their center of gravity considerably upwards and backwards. Also, they used the spring-like elasticity of the suit to get back up, as practiced in training.*

THE DETAILS: The way the astronauts regained their footing after a fall on the Moon appears unusual and too easy to non-expert viewers. But on the Moon the Apollo astronauts weighed one sixth of their Earth weight due to the lower lunar gravity, which is indeed one sixth of the Earth's. Their backpack and spacesuit weighed a total of approximately 81 kilograms (180 pounds) on Earth, which became a mere 13.5 kilograms (30 pounds) on the Moon. Their body weight was likewise reduced: an 80-kilogram (178-pound) person on the Moon weighs 13.3 kilograms (29.3 pounds).

In other words, on the Moon a fully suited astronaut weighed a total of about 30 kilograms (66 pounds). Getting up after a fall, therefore, was trivial in terms of effort. Doing it without toppling over again, however, was challenging.

The way the astronauts got back on their feet looks unusual because in addition to being in one-sixth gravity they were carrying a backpack (known as *PLSS*) which was quite heavy in proportion to their body weight (more precisely, its *mass* was considerable if compared to the mass of their body). Their PLSS weighed 26 kilograms (57 pounds) on Earth and 4.3 kilograms (9.5 pounds) on the Moon – one third of their body weight – and therefore displaced their center of gravity upwards and backwards. That's why they were always leaning forwards: to compensate for the heavy load on their backs.



Figure 6.5-1. Astronaut Charlie Duke picks himself up by pushing with this arms after falling forwards on the Moon at 144:35.24 mission elapsed time. Source: Apollo 16 Video Library *at Nasa.gov [http://tiny.cc/2i8idz].*

The video shown in Figure 6.5-1 is often referenced by conspiracy theorists as an example of these unusual maneuvers.

However, Charlie Duke, the Apollo 16 astronaut featured in this video, has explained in his many public talks that the footage actually shows a practical application of the special method that had been devised during simulations on Earth to take advantage of the elastic resistance of the spacesuit to get back up after a fall. During parabolic flights in aircraft

which simulated lunar gravity, Duke had found out that two or three "push-ups" were needed to spring back to an upright posture by rotating about his center of gravity.

Moreover, the wire theory fails because the Apollo TV footage includes unbroken sequences that last tens of minutes, during which the astronauts change direction and position repeatedly. How would the wires not get tangled up?

There's also the problem that the TV coverage includes many wide shots, which would require extremely long wires to keep the control rig and winch out of frame.

6.6 Does video show the astronauts' wires catching the light?



Figure 6.6-1. Detail of the flat VHF antenna stored on the backpack of astronaut Charlie Duke's suit (Apollo 16). Credit: K.C. Groneman and D.B. Eppler, NASA Johnson.

IN A NUTSHELL: *No. It shows reflections off the spacesuits' radio antennas, which take on unusual colors due to the process used to generate the color TV picture. Besides, why would NASA use shiny wires instead of black ones?*

THE DETAILS: The momentary glow that appears above the heads of the astronauts in some TV pictures isn't a studio light reflected by the hypothetical wires used to simulate low lunar gravity. It's usually a reflection off the radio antenna located at the top of the astronauts' backpack.

This antenna was flat and shiny (Figure 6.6-1), so it was hard to see it when its edges faced the camera but it became suddenly visible, reflecting the sunlight, when the astronaut turned (Figures 6.6-2 and 6.6-3).



Figure 6.6-2. A strange colored glow above an astronaut's head.

This glow appears just above the suit backpack (PLSS), exactly where the antenna was located.

This glow is often brightly colored for a very unusual reason, which can be understood only with the aid of in-depth knowledge of the technology used for the live TV transmissions from the Moon.



Figure 6.6-3. Another colored glint above the head of an astronaut [http://tiny.cc/go8idz].

The color TV camera used on the Moon actually had a black-and-white sensor with a color wheel (Figure 6.6-4) in front of it. The colored filters on this wheel rotated rapidly in front of the camera's sensor so as to generate a sequence of monochrome images filtered in red, green and yellow. These filtered images were then blended and processed electronically on Earth to reconstitute the original colors of the scene.

This system was sturdy and lightweight, but it had the drawback that if an object flashed rapidly in front of the camera it was caught by only one of the colored filters, acquiring a false coloring in the electronic processing.

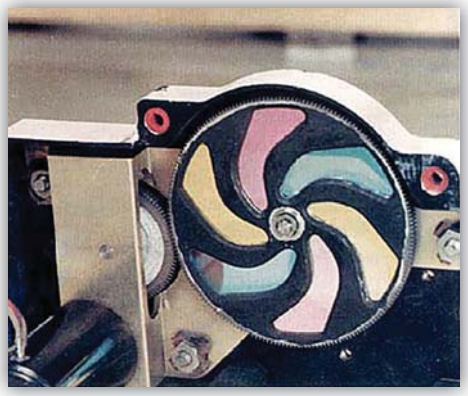


Figure 6.6-4. The rotating color filters of a lunar TV camera.

In other instances, the apparent reflection of light on wires is a *compression artifact*: a false image detail generated by repeated conversion and compression of a video, for example for posting on

the Internet. This sort of effect occurs in any digital video or photograph that is compressed and converted several times.

The original video footage of the lunar missions, which is the only valid reference for proper research, doesn't have these artifacts.

Besides, why would the perpetrators of the alleged fakery use shiny, reflective wires, when the wires commonly used in movie effects are nonreflective and black?



Figure 6.6-5. Nonreflective wires used in The Matrix *(1999).*

6.7 Why did the astronauts only make such low jumps?

IN A NUTSHELL: *They might look low until you consider that the astronauts were wearing a suit and backpack that doubled their weight and had very limited flexibility, and that a fall on the airless Moon could have killed them.*



Figure 6.7-1. The video recording of John Young's lunar jump during Apollo 16. The other astronaut, on the right, is Charlie Duke [http://tiny.cc/rt8idz].

THE DETAILS: One of the best-known lunar jumps is the one performed by John Young as he saluted the American flag during one of the Apollo 16 moonwalks. Figure 6.7-1 shows the video recording of

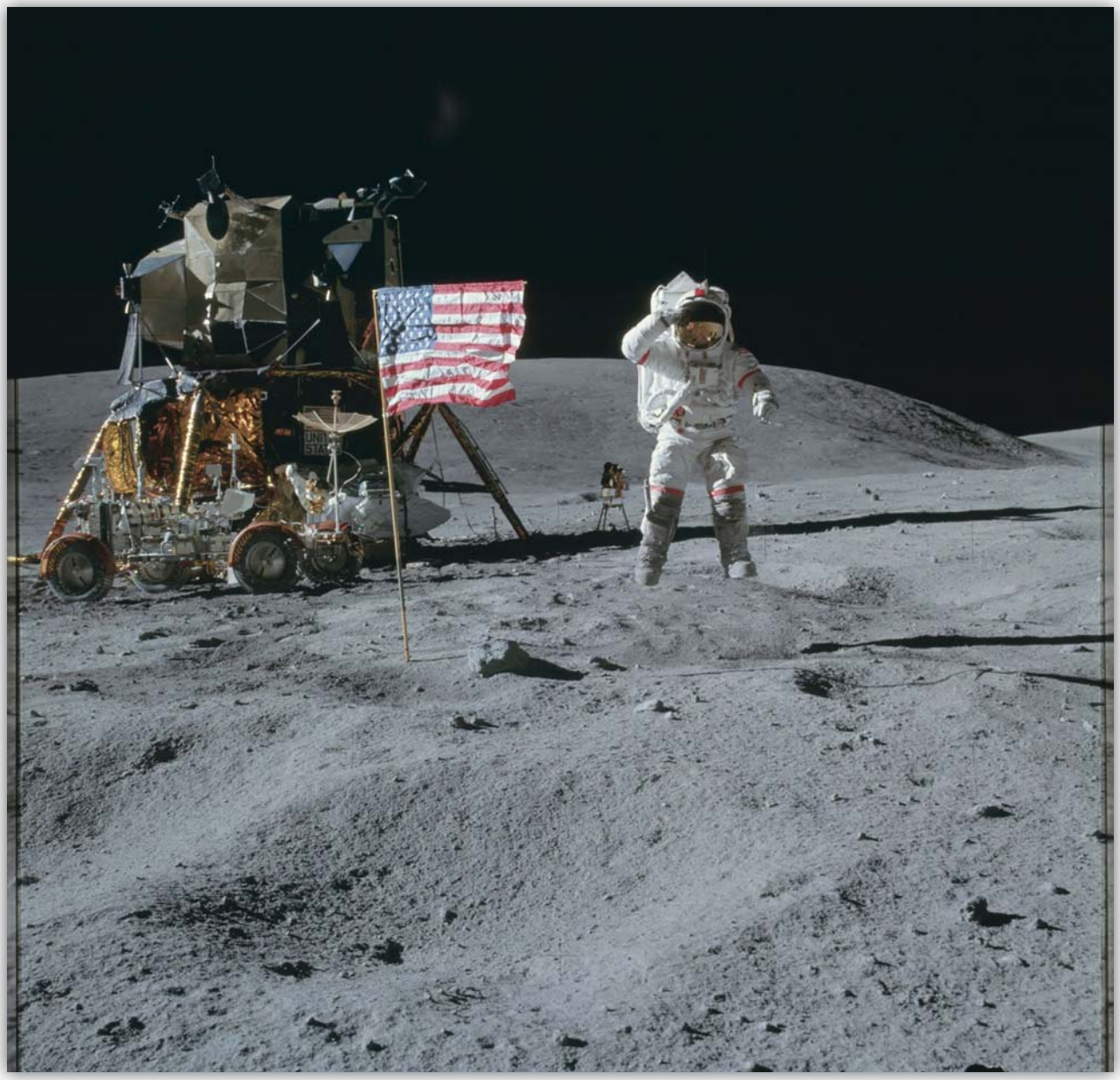


Figure 6.7-2. John Young's lunar jump, photographed by Charlie Duke (AS16-113-18339).

this event, which was also photographed by Charlie Duke (Figure 6.7-2).

Moon hoax proponents say that Young's hop is strangely short and so are all the other lunar jumps. They argue that on the Moon, with one-sixth of Earth's gravity, astronauts should be able to perform amazing leaps, maybe six times as high as on Earth. Perhaps the hidden wires couldn't lift them high enough or fast enough?

Actually, there are very practical reasons for these short hops.

- First of all, every lunar astronaut was wearing a spacesuit and a backpack that weighed, on Earth, about 80 kilograms (176 pounds): as much as the astronaut himself. Although on the Moon this gear weighs one sixth of its Earth weight, i.e., about 13 kilograms (28 pounds), it is still a substantial extra ballast that the astronaut has to lift in order to jump.
- In space and on the Moon it is necessary to distinguish between *weight* and *mass*: weight decreases in a low-gravity or zero-gravity environment, but mass remains unchanged and therefore inertia is the same as on Earth. Therefore the leaping astronaut had to overcome the inertia of his 80-kg (176-lb) gear and of his own body just like on Earth.
- John Young performed a standing jump, with no run-up, as shown in the video of Figure 6.7-1, and this limited the energy that he could put into the jump.
- Young was wearing a very bulky and stiff suit, limiting his freedom of motion and therefore again the energy he could put into his leap by bending his legs and moving his arms (Figure 6.7-3).
- More importantly, the astronaut was on the Moon, surrounded by a deadly vacuum. He was well aware that if he fell and cracked his helmet, damaged the backpack that supplied him with air and cooling or tore his pressurized inner suit, he would die by decompression or suffocation. In such conditions, it was rather wise not to try and set high-jump records.



Figure 6.7-3. John Young just before his allegedly controversial standing jump. Note the very limited bending of his legs.

Many hoax theorists also make the mistake of considering Young's jump as the highest ever made on the Moon. Actually, it was just a hop intended to take an unusual salute photograph. Other jumps were much higher and correspondingly more dangerous.

For example, Neil Armstrong reported that he jumped up to the third rung of Apollo 11's LM ladder, which was *"easily five or six feet* [150-180 centimeters] *above the ground"*.[1] His leaps are visible in the recordings of the

1 *Apollo 11 Technical Crew Debriefing*, 31 July 1969, in *NASA Mission Reports - Apollo 11*, Vol. 2, Apogee Books, p. 89 (page 10-61 in the original numbering).

TV transmission of his moonwalk (Figure 6.7-4).



Figure 6.7-4. Neil Armstrong's leap to climb back into the LM at the end of the Apollo 11 moonwalk, in the restored footage of the live TV transmission (to the right of the flag, in the shadow of the LM, at 2:16:40) [http://tiny.cc/nx8idz].

However, Armstrong refrained from further experimentation, because he noted that *"there was a tendency to tip over backward on a high jump. One time I came close to falling and decided that was enough of that."*[2] A backward fall would in fact have entailed the risk of seriously damaging the suit backpack, forcing to cut short the moonwalk.

Young himself and his crewmate Charlie Duke engaged in a televised high-jump contest at the end Apollo 16's third moonwalk. Duke estimated that Young had jumped *"about four feet* [120 centimeters]*"* (Figure 6.7-5); Duke made an equally high jump, but fell backwards onto his backpack.

2 *Apollo 11 Technical Crew Debriefing*, 31 July 1969, in *NASA Mission Reports - Apollo 11*, Vol. 2, Apogee Books, p. 76 (page 10-28 in the original numbering).

In his book *Moonwalker*, he reported that it was *"the only time in our whole lunar stay that I had a real moment of panic and thought I had killed myself. The suit and backpack weren't designed to support a four-foot fall. Had the backpack broken or the suit split open, I would have lost my air. A rapid decompression, or as one friend calls it, a high-altitude hiss-out, and I would have been dead instantly. Fortunately, everything held together."*[3]



Figure 6.7-5. Young and Duke do high-jumps on the Moon and Duke falls [http://tiny.cc/xz8idz].

3 *Moonwalker* by Charlie and Dotty Duke, p. 206.

6.8 Is the "Moontruth" video an outtake from the fake TV broadcast?

IN A NUTSHELL: *No, it's a prank, specifically a viral video shot in 2002 by a British advertising company.*

THE DETAILS: A video widely available on the Internet is often presented as a leaked outtake from the faking of the Apollo 11 moonwalk, showing Neil Armstrong as he climbs down the ladder of the Lunar Module and starts to say *"That's one small step for man, one giant leap for m..."* until an overhead bank of studio lights comes crashing down and a film crew comes into view while a director's voice yells *"Cut!"*.



Figure 6.8-1. The Moontruth *video (The Viral Factory, 2002) [http://tiny.cc/628idz].*

This video can be recognized by the *Moontruth.com* caption, but it's not evidence that the Moon landing videos were faked and the outtakes were leaked: it's actually an Internet prank created in 2002 by The Viral Factory, an advertising agency based in London, United Kingdom, to promote itself through word of mouth and create buzz (pun intended) about its work.

Today Moontruth.com is an empty shell, but in 2002 it was owned by the British ad company (as documented by a Whois ownership query conducted at the time) and it contained text that claimed that the video was an *"Apollo 11 Moon Landing Footage Out-take."* However, easily revealed hidden pages explained the prank:

> *The clip is FAKED. It is not an out-take leaked from a NASA top secret reel. It was done in a studio, for fun, and to entertain webheads like us.*
>
> *Yes, the clip is fake. It was shot in a studio in London in spring 2002. It was based on an idea by director Adam Stewart, who was a space exploration nut. He had read the conspiracy theory sites and decided he wanted to make a spoof based on the idea that the Apollo 11 moonlanding was faked.* [...]
>
> *We shot on original 1960's Ikegami Tube Camera in Mount Pleasant Studios in London. The guy in the suit is an actor. The rest of the 'cast' were basically the crew, who thought the idea was very funny and wanted to be in it.*

The landing craft and 'moonscape' were a set built by our art director, Richard Selway. The ladder that 'Neil' descends was made according to original blueprints that were downloaded off the Net. The rest of the set was built to match the original as closely as possible.

The moon surface was cement dust. It was disgusting. Even with the studio ventilation on full it got everywhere, and at one point there was so much of it floating round, the lights were flaring really badly.

The footage was treated in post-production to give 'Neil' his weightlessness and the ghosting effect of the original. We re-recorded and processed the soundtrack to recreate the effect of sound traveling all the way from the moon.

We think it's pretty convincing, and one thing's for damn sure – it was a lot cheaper than really going to the moon.

This explanation is currently preserved at Archive.org and the true origins of this video are recorded in detail by the well-known Snopes.com hoax debunking site. A few videos showing the production of the clip are still available online (Figure 6.8-3).



Figure 6.8-2. The explanation of the Moontruth *video (2002), preserved at Archive.org.*

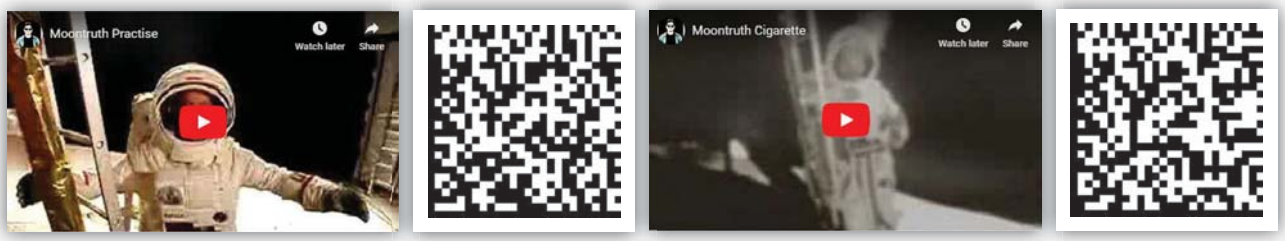


Figure 6.8-3. Behind-the-scenes footage from Moontruth *(2002) [http://tiny.cc/768idz e http://tiny.cc/g98idz].*

6.9 How come Kubrick's widow, Buzz Aldrin and others have confessed on film?

IN A NUTSHELL: *Because the "confessions" are part of a 2002 French mockumentary,* Opération Lune*, which includes interviews with Buzz Aldrin, Henry Kissinger, Donald Rumsfeld, Christiane Kubrick and other authoritative figures, who openly say on camera that the Moon landings were faked. But in the final part of the mockumentary the interviewees reveal that the confessions are just an art prank.*

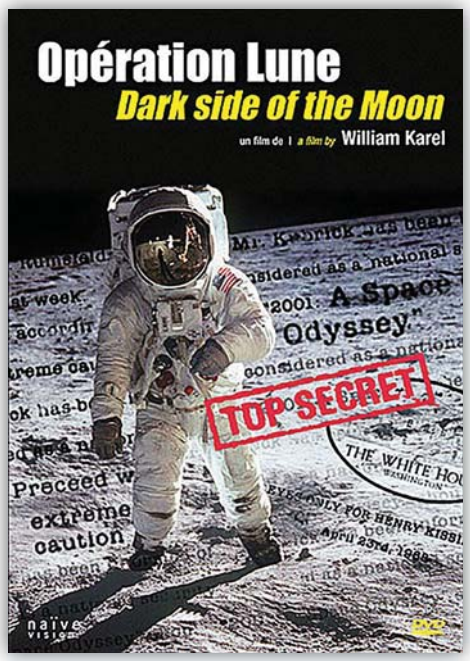


Figure 6.9-1. The cover of the original French and English version of Opération Lune *on DVD.*

THE DETAILS: A series of videos with astonishing confessions about the Moon landings made by former US Secretary of State Henry Kissinger, former US Secretary of Defense Rumsfeld and Christiane Kubrick (director Stanley Kubrick's widow) and Apollo 11 astronaut Buzz Aldrin, among others, is easily available on the Internet. These are not lookalikes and there is no lip-synching by voice impersonators: it's actually them saying these things.

But it's all part of a cleverly orchestrated prank, a mockumentary directed in 2002 by William Karel and broadcast by European TV network Arte as *Opération Lune* (also known as *Dark Side of the Moon* in English and as *Kubrick, Nixon und der Mann im Mond* in German).



Figure 6.9-2. The German edition of Opération Lune *by William Karel [http://tiny.cc/qr7jdz].*

The German edition of *Opération Lune* is available as pay-per-view on YouTube (Figure 6.9-2).

Karel's *Dark Side of the Moon* was originally a single, 52-minute fake documentary intended to test the gullibility of viewers and play with their sense of reality until the end, when the trick is revealed, but it soon found its way onto the Internet, where it was cut into shorter segments, which were presented out of context and often without including the explanation at the end. Accordingly, it is often cited as evidence by Moon hoax theorists, thus proving, albeit in an unintended way, Karel's point about gullibility and the excessive authoritativeness we grant to celebrities.

The mockumentary actually contains several hints to its true nature: for example, if one listens carefully to what Aldrin, Kissinger and Rumsfeld say, it becomes evident that their words are being taken out of context; many of the historical events mentioned are blatantly wrong or false;

and several of the names of the interviewees are lifted from famous movies, such as Jack Torrance (from *Shining*), David Bowman (from *2001: A Space Odyssey*, Figure 6.9-3), Ambrose Chapel from Hitchcock's *The Man Who Knew Too Much*, Eve Kendall and George Kaplan (both from *North by Northwest*).



Figure 6.9-3. A still from William Karel's Opération Lune (Dark Side of the Moon) *(Arte TV, 2002).*

The end credits also include the outtakes and bloopers made by the famous people interviewed and turned into improvised actors by Karel, who ask the director whether they has been believable.

Even if the clips from the mockumentary are viewed without context, common sense should raise an obvious question: if the Moon landings were a crucial and secret fakery, why are these people talking about it and revealing it so openly and nonchalantly?

Some conspiracy theorists have an explanation for this, too: they assume that *Opération Lune* is actually a *fake* mockumentary intended to cover up the original fakery or prepare the general public for the eventual disclosure of the truth.[4]

4 This claim, archived at Archive.is, is made for example by Massimo Mazzucco, creator of the *American Moon* conspiracy video.

The power to convince of this kind of documentary was demonstrated eloquently in June 2004, when a group of scientists was invited to see *Opération Lune* at the Pierre et Marie Curie University in Paris and discuss it with its director. Their reactions (Figure 6.9-4) when they discovered that they had been deceived by the director's skill and by the power of images and of selective editing are an excellent example of the fact that culture and scientific knowledge in other fields are not necessarily sufficient to notice a cleverly executed con: this requires people who are expert in the specific field of spaceflight and of movie effects.



*Figure 6.9-4. Full recording of the debate with scientists held at the Pierre et Marie Curie University and William Karel on 1 June 2004 (*Operation Lune Debat avec William Karel, Réalisateur du Documentaire*). Other copies are available:* Conférence publique sur le documentaire Opération Lune avec son réalisateur; Débat avec William Karel autour de son film Opération Lune*. [http://tiny.cc/577jdz].*

6.10 How could NASA conveniently "lose" the tapes of the first Moon landing?

IN A NUTSHELL: *They lost the raw tapes, but copies of all footage still exist. Specifically, NASA lost the* direct *TV recording of the first landing, which was made using a nonstandard format and was thought to be useless once converted to normal TV in the best possible way. The lower-quality* converted *recordings have not been lost. The lost tapes did not contain extra footage or different views.*

THE DETAILS: As described in the technical primer at the beginning of this chapter, in the 1960s even achieving a fuzzy, black-and-white live broadcast from the Moon for the first landing required a substantial technological effort. Due to weight, power and other technical constraints, a non-standard miniaturized TV camera and a low-quality signal had to be used on the Moon, producing pictures that were less sharp than normal TV. These pictures had to be received on Earth and converted on the fly for worldwide live broadcast. This process caused considerable loss of quality.

The conversion was done in the only way available at the time: at the large radio telescopes that received the nonstandard TV signal directly from the Moon, a standard TV camera was pointed at the special monitors that were capable of displaying the pictures.

NASA recorded this *converted* television signal on standard videotape reels of the best quality available at the time. These tapes have *not* been lost (Figure 6.10-1).



Figure 6.10-1. One of the converted videotape reels of the Apollo 11 flight. Credit: DC Video.

The non-standard *direct*, *unconverted* signal from the Moon could not be recorded with ordinary video recording equipment, so NASA stored it on a track of the telemetry tapes of the flight.

However, this meant that these tapes were labeled as ordinary mission telemetry and were placed in storage with all the other technical records at the end of each mission. Several years after the end of the Apollo project, the stored telemetry was deemed of no further interest and its expensive tapes were sent to be wiped for reuse; this was standard practice at the time. The best-quality recordings of the Apollo 11 lunar excursion were thus deleted unintentionally.

These are the so-called "lost tapes": they included no extra footage or different shots compared to the recordings that are currently available. However, they would have offered

a far better view, in terms of detail and clarity, of that unique moment of history: we know because some of the engineers who worked at the receiving stations, such as Ed von Renouard and Bill Wood, took photographs and movies of the monitors that displayed the unconverted pictures (Figures 6.10-2 and 6.10-3). These unofficial recordings include the only existing footage (made by von Renouard on a Super 8 movie camera) of the jettison of the astronauts' backpacks after they reentered the Lunar Module.



Figure 6.10-2. Neil Armstrong in the live TV signal as broadcast from Houston (left) compared with the original signal received from the Moon at Goldstone (right, NASA image S69-42583) as recorded by taking a Polaroid photograph of the TV screen of the receiver on Earth. The black band is caused by the short exposure time of the camera and the slowly forming TV picture.



Figure 6.10-3. Armstrong and Aldrin at the foot of the Lunar Module ladder uncover the commemorative plaque on the spacecraft, as photographed in Houston from a standard TV monitor (left) and at the Parkes radio telescope, in Australia, from a monitor that displayed the direct, unconverted signal (right). Credit: Honeysucklecreek.net.

NASA's handling of the original recordings seems unforgivably reckless and absurd today, but it should be noted that at the time it was widely believed that nothing better could be extracted from the master tapes. The digital image processing that we now take for granted was still in its infancy and the converted footage was considered good enough, especially compared to the quality of 1960s TV broadcasts, which was very low compared to today's high-definition images.

In 2009, NASA published a detailed report (*The Apollo 11 Telemetry Data Recordings: A Final Report*) on the extensive international search for the missing master tapes and hired Lowry Digital, a film restoration company, to assemble, clean

up and enhance the best available converted recordings with assistance from many of the engineers who had worked on the original transmission. The restored Apollo 11 moonwalk is now available online (*Restored Apollo 11 Moonwalk Video*).

Despite the restoration, the loss of the original recordings remains regrettable and is mitigated only partially by the faint hope that unofficial copies of the raw transmission might still surface from various sources.

6.11 Does never-before-seen footage show astronauts faking the view of Earth from deep space?

IN A NUTSHELL: *No. The footage has always been available and isn't fake. Had it been shot from low Earth orbit through a circular window to make the Earth look small and distant, as some conspiracy theorists claim, it would show the clouds changing continuously as the spacecraft flies over different parts of the planet. They don't.*

THE DETAILS: Moon hoax theorist Bart Sibrel, in his video *A Funny Thing Happened on the Way to the Moon* (2001), shows an Apollo 11 video recording that he claims to be *"never before seen or heard footage"* in which the astronauts allegedly faked being far from Earth when they were actually still in low orbit around it.

According to Sibrel, they *"placed the camera at the back of the spacecraft and centered the lens on a circular window in the foreground, outside of which it is completely filled with the Earth in low orbit. The circumference of the window then appears to be the diameter of the Earth at a distance, with the darkened walls of the spacecraft appearing to be the blackness of space around it."* (Figure 6.11-1).



Figure 6.11-1. A frame from the allegedly faked Apollo 11 video, as shown by Bart Sibrel.

In other words, according to Sibrel's theory, the astronauts used the circular window to mask the bulk of the Earth and only show a circular portion of its surface, thus creating the illusion of a distant floating sphere.

In actual fact, the footage is not at all *"never before seen or heard"* as Sibrel alleges. It is part of a series of color TV transmissions made by the Apollo 11 astronauts on their way to the Moon, 10.5 hours and 34 hours after liftoff, when they were respectively 94,500 and 240,000 kilometers (51,000 and 130,000 nautical miles) from Earth. The full recording has been available for a long time, for example on the Apollo 11 DVDs published by Spacecraft Films.



Figure 6.11-2. The first of two live TV broadcasts made by Apollo 11 far from Earth matches Sibrel's allegedly "never before seen" footage [http://tiny.cc/zd8jdz].

Sibrel's version is recut out of sequence: the unedited footage simply shows the astronauts preparing for TV transmissions and testing the camera settings. This is evident by listening to their communications in full, as available in the *Apollo Flight Journal* (*Day 1, part 4: Navigation and Housekeeping* and *Day 2, part 2: TV Transmission*), instead of taking selected quotes out of context. These communications report that the pictures



Figure 6.11-3. Shannon Walker gazes at the Earth, specifically at the Caribbean region, through the circular window of the Cupola on the International Space Station. Source: NASA/ Flickr.



Figure 6.11-4. Earth from the Cupola's circular windows in a photograph taken by Scott Kelly. Fonte: NASA/Flickr.



Figure 6.11-5. Another view of Earth from the ISS, at an altitude of approximately 400 kilometers (280 miles). Source: ESA.



Figure 6.11-6. Earth clouds viewed from the Cupola. Source: NASA/ SpaceRef.

show the eastern Pacific Ocean, the west coast of North America and the southern coast of South America (north is down and to the left).

Moreover, the camera trick alleged by Sibrel wouldn't have worked even if the astronauts had tried it. If the Apollo spacecraft had been in low orbit around the Earth, with its TV camera peeking through a circular mask at a small portion of the planet below, the footage would have shown ever-changing clouds and parts of the planet rolling by as the spacecraft rapidly circled the globe. The uncut, less grainy version of the video presented by Sibrel instead shows exactly the same unchanging cloud patterns for as much as fifteen minutes.

We can check what Earth would have looked like through a circular window in low Earth orbit by looking at the photographs taken from the International Space Station (ISS), at an altitude of 400 kilometers (248 miles). The difference is rather obvious.

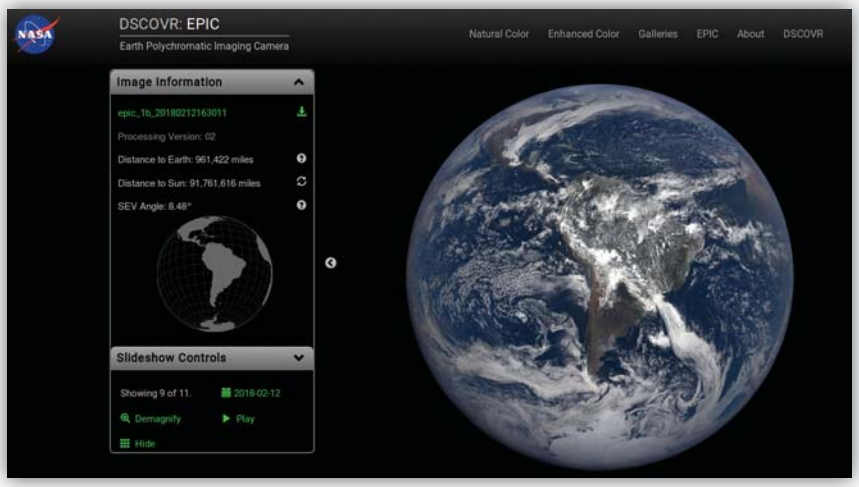


Figure 6.11-7. Earth as seen by the EPIC camera of the DSCOVER space probe, located 1.5 million kilometers (930,000 miles) away from the planet, on 12 February 2018. Source: NASA.

Figure 6.11-7 instead shows what the Earth looks like from a distance of 1.5 million kilometers



Figure 6.11-8. Comparison between Apollo 11 photo AS11-36-5337 and the Sibrel image (rotated so that north is up). North America is in the upper right portion.

(930,000 miles). Once again, the difference is quite conspicuous.

This is confirmed by photograph AS11-36-5337, which was taken approximately at the same time as the TV transmissions and shows the same cloud patterns, allowing to determine that the TV picture disputed by Sibrel actually shows the entire North American continent and most of the Pacific Ocean (Figure 6.11-7). This would be impossible from low Earth orbit.



Figure 6.11-9. Detail of photo AS11-36-5337, showing the North American continent.

6.12 Why is there no exhaust from the LM's ascent rocket engine?

IN A NUTSHELL: *Because there shouldn't be. Rocket motors don't generate a fiery exhaust in the vacuum of space. Rockets that use the same propellant as the Lunar Module don't generate a visible plume even in the Earth's atmosphere. The same effect occurred with the Shuttle main engines and with Gemini Titan rockets, for example.*

THE DETAILS: Bill Kaysing, in Fox TV's *Did We Land on the Moon?* (2001), objects that *"In the footage of the ascent stage going up, what you don't see is an exhaust plume coming out of the rocket engine nozzle... What do we see? We see the ascent stage suddenly pop up without any exhaust plume whatsoever as though it were jerked up by a cable"*.



Figure 6.12-1. Liftoff of the Apollo 17 Lunar Module on 14 December 1972, as shown by the live TV broadcast sent by the remote-controlled camera installed on the Rover [http://tiny.cc/uu8jdz].

It's true that the liftoff footage doesn't match the illustrations



Figure 6.12-2. Artist's illustration of the liftoff of the Lunar Module from the Moon, dated 1966. Source: NASA photo S66-5094, scanned by Mike Gentry and Jody Russell, NASA Johnson, ALSJ.

that NASA published in 1966, showing a very conspicuous plume under the Lunar Module's ascent stage (Figure 6.12-2).

Actually, there's no visible exhaust plume in the TV footage for a very simple reason: there shouldn't be one. Rockets don't usually produce persistent and extensive plumes in the vacuum of space. Artist's illustrations are, indeed, *art*, and as such they take liberties in order to represent motion and explain what's going on. If the drawing shown in Figure 6.12-2 didn't show a plume, the general public for whom it was intended would have seen a spacecraft mysteriously floating above the Moon. Adding the plume is not scientifically accurate, but it's a self-explanatory way to illustrate the fact that the spacecraft is being propelled by its rocket motor.



Figure 6.12-3. Separation of the first stage of a Saturn V. The rocket engines of the second stage are ignited but don't produce plumes [http://tiny.cc/lx8jdz].

The lack of a plume in vacuum is documented for example in the footage from the Saturn V test flights, the authenticity of which is not disputed by conspiracy theorists (Figure 6.12-3).



Figure 6.12-4. Slow motion footage of the ignition of the S-IVB second stage of a Saturn 1B rocket during test mission AS-202, as viewed by an automatic film camera installed inside the top portion of the first stage. After a brief ignition blast, this rocket engine also doesn't produce a visible plume in vacuum [http://tiny.cc/j08jdz].

Recent space flights, such as SpaceX's Falcon 9 booster missions, likewise have no plume once they're out of the Earth's atmosphere. This can be seen for example in Figure 6.12-5, which is a still from the 2018 launch of satellite Paz.

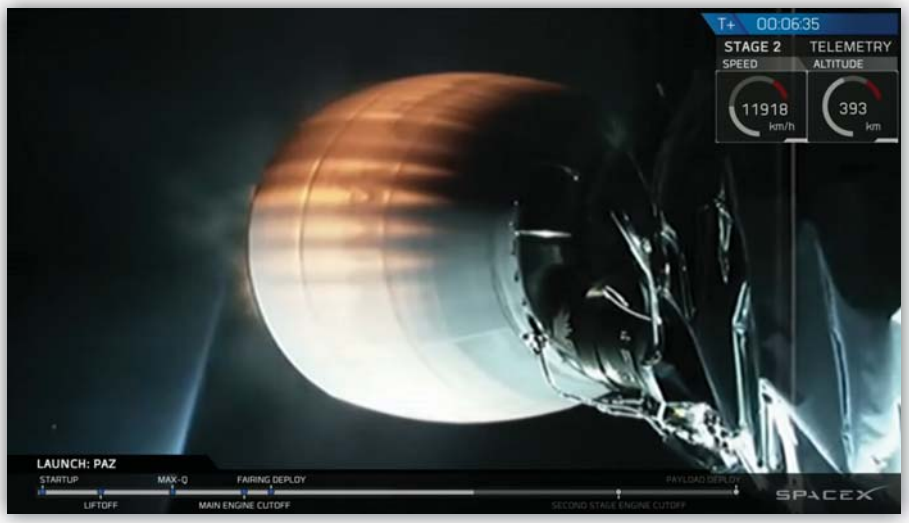


Figure 6.12-5. The motor of the second stage of SpaceX's Falcon 9 rocket is firing, as shown by its red-hot nozzle, but it doesn't produce a plume in the very thin air it encounters 393 km (244 miles) above the Earth. Source: SpaceX live broadcast.

Moreover, the Apollo LM used a mix of Aerozine 50 (50% hydrazine, 50% unsymmetrical dimethyl hydrazine) and dinitrogen tetroxide, which are *hypergolic*, i.e., they react spontaneously as soon as they come into mutual contact. This allowed a simple and highly reliable engine design. The

product of the reaction of these substances is colorless and transparent: that's another reason why there's no visible plume under the LM as it takes off from the Moon.

The same type of propellant used in the LM was also used in the massive Titan launchers used in the Gemini manned spaceflight program (and also used as nuclear warhead delivery missiles), and their liftoffs produced a surprisingly small and colorless plume, with no flames, even in air (Figure 6.12-6).

The Space Shuttle's maneuvering thrusters also used hypergolic propellants and likewise produced no significant plume. Its three main engines also produced an almost colorless exhaust plume as they burned hydrogen and oxygen, whereas its solid-propellant side boosters generated a massive, fiery trail, as shown in Figures 6.12-7/8/9.



Figure 6.12-6. Liftoff of a Titan rocket carrying the Gemini 12 spacecraft on November 11, 1966. Note the almost colorless engine exhaust and the lack of flames.



Figure 6.12-7. The main engines of the Space Shuttle (left) have an almost colorless, transparent exhaust, while the solid-propellant boosters (right) produce a very conspicuous plume. Credit: NASA/Rusty Backer and Michael Gayle.



Figure 6.12-8. The Space Shuttle main engines at ignition (source: FSG).



Figure 6.12-9. Another view of the Shuttle main engines at ignition, showing the see-through exhaust (source: FSG).

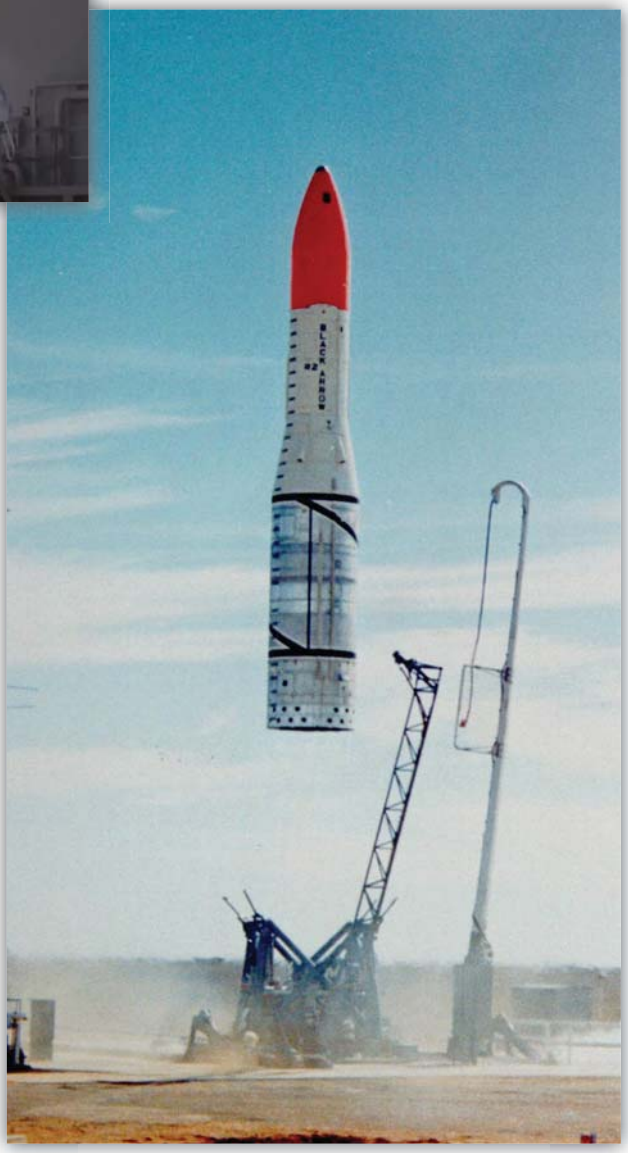


Figure 6.12-10. The flameless liftoff of a British Black Arrow satellite launcher (1969-1971).

6.13 Why did Apollo 11 transmit color TV from space but not from the Moon?

IN A NUTSHELL: *Different cameras, transmitters and antennas. Apollo 11's Command Module had better and more powerful TV equipment than the Lunar Module. It could send a good color TV signal to Earth; the LM could not. Later missions carried improved cameras and equipment that allowed color TV from the Moon as well.*

THE DETAILS: It may seem rather suspicious that Apollo 11 sent live color TV pictures during the trip (Figure 6.13-1) and even from lunar orbit but then switched to black and white for the all-important moonwalk.

Indeed, Bart Sibrel, in *A Funny Thing Happened on the Way to the Moon*, notes this discrepancy and suggests that the perpetrators of the hoax decided it would be *"better to open their debut mission with fuzzy pictures and numerous blackouts rather than show too much revealing detail of a false scene that was yet unproven"*.



Figure 6.13-1. Buzz Aldrin in the LM as the Apollo 11 spacecraft approaches the Moon, in a frame from the color TV transmissions sent using the Command Module camera and transmission equipment. Detail from NASA image S69-39532.

The actual reason for the switch was that the color transmissions were made using the Command Module's TV camera and onboard transmission equipment, which was far more sophisticated (but unable to withstand the extreme temperature variations of a moonwalk) and powerful than the Lunar Module's and also had a better, larger antenna.

The Command Module was powered by fuel cells, while the LM only had batteries, and this allowed the CM to spend more power on the TV signal.

Moreover, the transmission gear of Apollo 11's LM lacked the bandwidth needed to send a color signal, while the CM had no such limitation. However, the CM could not be used as a relay because it orbited around the Moon every two hours and therefore was often out of contact with the LM or Earth or both.

Later missions used lunar modules equipped with more advanced and compact TV cameras and with greater power reserves, and deployed a large unfolding parabolic antenna (Figure 6.13-2) which allowed to transmit from the lunar surface with enough power to carry a color TV signal. Apollo 11 also had this antenna, but its deployment would have required twenty minutes out of the two hours available for the first moonwalk, so after NASA saw that the TV pictures from the Moon were good enough without this antenna they decided not to use it for this first mission.

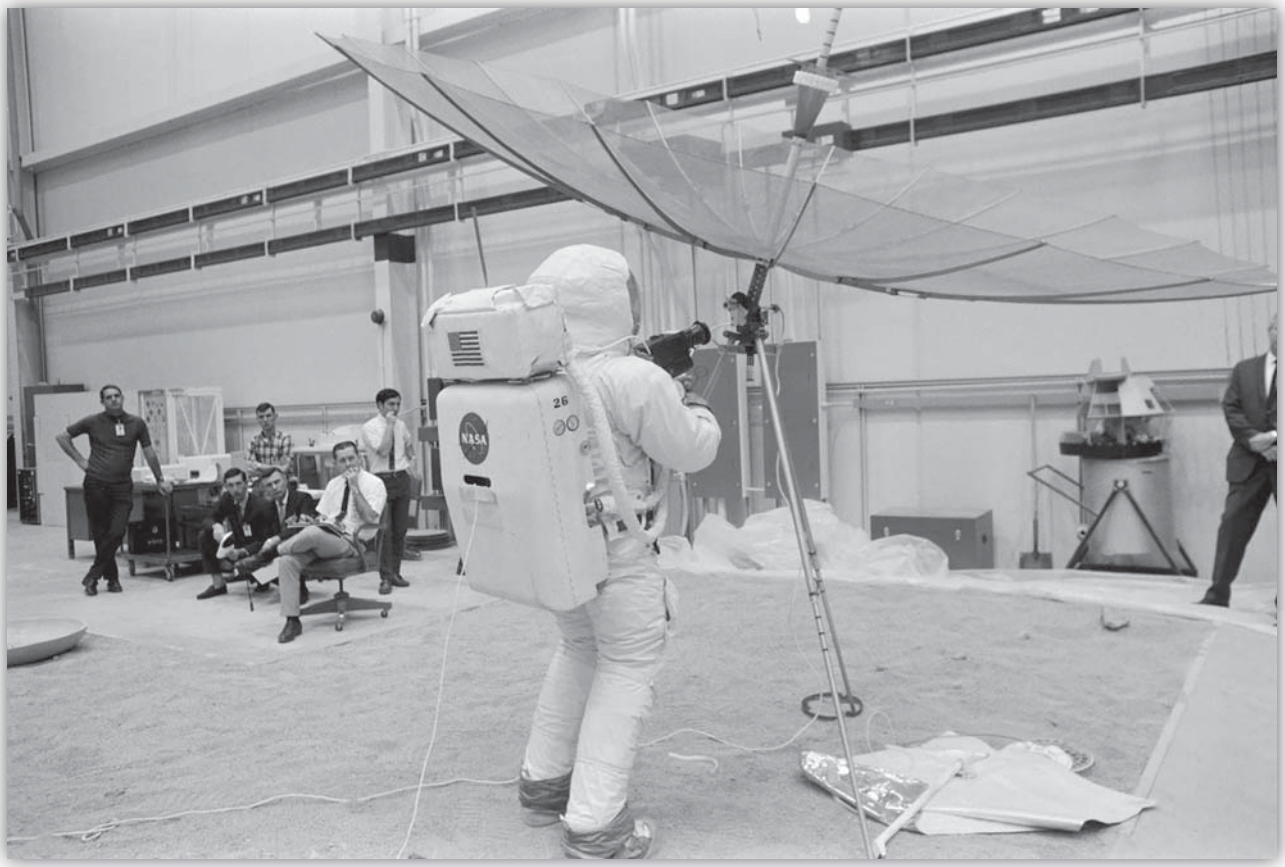


Figure 6.13-2. An astronaut (probably Armstrong or Aldrin) during training to deploy the large parabolic lunar antenna after unfolding it. Photo AP11-S69-31179.

6.14 Why does the Moon look the same in two different places? Recycled Moon sets?

IN A NUTSHELL: *Because they're not two different places. A NASA documentary incorrectly edits two video clips of Apollo 16's lunar excursion as if they were shot in different places on different days, but in the original raw footage the two clips are only seven minutes apart and belong to a long, unbroken sequence that occurs in a single location.*



Figure 6.14-1. A frame of the first clip disputed by Fox TV and Sibrel.



Figure 6.14-2. A frame from the second clip in dispute.

THE DETAILS: Bart Sibrel's video *The Rocks Cry Out: Apollo 16 Anomaly* and the Fox TV show *Did We Land on the Moon?* accuse NASA of using the same location or movie set for two different sites of the Apollo 16 mission, which according to other NASA documents were located four kilometers (over 2.5 miles) apart and were visited on two different days (Figures 6.14-1 and 6.14-2).

The first clip (Figure 6.14-1) shows a single astronaut and is captioned *"Day One"* by Fox, while the second one (Figure 6.14-2) features two astronauts and is labeled *"Day Two"*, but the location is unquestionably the same. Even the camera angle is identical.

According to the Fox show, *"NASA claims the second location was two and a half miles away, but when one video was superimposed over the other, the locations appear identical."*

However, reviewing the full set of TV transmissions from Apollo 16 (as published for example by Spacecraft Films) reveals another story. In the original transmissions, the images in the two video clips are not referred to two separate days: they're just *seven minutes* apart and belong to a single, unbroken sequence recorded during Apollo 16's second day on the Moon, at 144 hours and 48 minutes and 144 hours and 55 minutes in mission elapsed time. They also refer to the same location. In other words, the accusations of fakery are bogus.

Moreover, the audio in the clips presented by Fox TV and Sibrel doesn't match the recordings of reference. For example, according to NASA's *Technical Air-to-Ground Voice Transcripts* the phrase *"Well, I couldn't pick a better spot"* in the first clip actually comes from the first day of Apollo 16 on the Moon, at 123 hours and 58 minutes, and the words *"That is the most beautiful sight"* and *"It's absolutely unreal!"* occur at 124 hours and 3 minutes and 144 hours and 16 minutes respectively.

The most likely source of this mismatch is a documentary commissioned by NASA to A-V Corporation in 1972 and rather ironically entitled *"Nothing So Hidden..."*, in which the

clips have the same, incorrect audio presented by Sibrel and Fox TV and are shown as if they had been taken on different days.

In other words, Sibrel and Fox referenced a documentary instead of referring to the original footage, which is the only valid reference material. Their entire allegation is based on this fundamental error.

The alleged evidence of conspiracy is just an editing mistake in a documentary produced by a non-NASA company. Editing mistakes in documentaries are not evidence of NASA fakery; they're merely evidence of inaccurate editing. Unfortunately, such mistakes or artistic licenses are frequent in supposedly faithful documentaries and often alter the understanding of an event. For example, as space historian James Oberg notes about Apollo 11,

> *A far more serious distortion appears in most — but not all — television documentaries of the mission. Since the "small step" was really so small and his body movement so subtle, the video of this event is not dramatic enough for some programs. Instead, the audio track of the first words is transferred forward about a minute to coincide with Armstrong's first jump down the ladder to the footpad. This turns the poetic "small step" into an awkward big hop. That may satisfy action-oriented entertainment values but it is false history. It is untrue to the significance of Armstrong's words.*[5]

5 *Getting Apollo 11 Right - Commemorating What Really Happened*, James Oberg, ABCNews.com (1999).

6.15 Is this video found footage from the movie set where the Moon landings were faked?

IN A NUTSHELL: *No, it's altered footage from the 1978 science fiction movie* Capricorn One*.*

THE DETAILS: A black-and-white video published by the British *Daily Star* news website in 2018 is described as coming from the *"cutting room floor of the film editing department of the Texas State film production company, marked between 1966-1972"* and was allegedly *"discovered in a shoe box in 2017"*. According to the *Daily Star*, it shows *"film crews setting up cameras on a surface that looks identical to the white exterior of the moon."*



Figure 6.15-1. A frame of the Daily Star video shows stage lights, a light-colored background and two people in white clothes next to the descent stage of a Lunar Module.

But anyone who is familiar with science fiction movie history will recognize this footage immediately: it's from the production of the 1978 movie *Capricorn One*, which tells the story of a badly faked human mission to Mars.

Here is a comparison of frames from *Capricorn One* and from the *Daily Star* video. It becomes quite clear that the allegedly discovered footage has been turned to black-and-white to hide the reddish color of the fake Martian soil, which would have to be gray to fake the Moon.



Figure 6.15-2. Another frame from the video shows two people in white, one in black, the descent stage of a Lunar Module and a mockup of an Apollo Command Module.

Moreover, the light-colored background behind the Lunar Module makes no sense for faking the Moon, where the sky is black.



Figure 6.15-3. A frame from Capricorn One *(at 19:21) shows the same lights, the same people dressed in white and black, the same light-colored background and the same Command Module mockup. The black-and-white images are flipped with respect to this frame.*



Figure 6.15-4. Another frame from the Daily Star *video.*



Figure 6.15-5. A frame from Capricorn One *shows that Figure 6.15-4 is merely a cropped, blurred and black-and-white version of this scene of the movie. Even the studio lights match perfectly.*

7 Alleged technological anomalies

It's fairly easy to refute the accusations of Moon hoax believers when they relate to alleged anomalies in the visual record of the Apollo missions, as shown in the preceding chapters: usually it just takes time, common sense and a little knowledge of photography.

Things get harder when the debate moves to alleged technological absurdities or anomalies regarding the Apollo missions: many objections can't be debunked without in-depth technical and historical knowledge.

7.1 If we could go to the Moon with 1960s technology, why haven't we ever gone back?

IN A NUTSHELL: *Because it's very difficult, very expensive and very dangerous, and there's no longer a political imperative that justifies risking lives and devoting massive resources to the challenge as it did in the 1960s. The Cold War is over; the Soviet Union, once the rival to beat in the space race, no longer exists. There's no non-political reason to go back with crewed missions; robots can do the job far more cheaply and safely. That doesn't mean that we can't, couldn't or didn't. Also, 1960s technology wasn't that primitive: it even included things we don't have today, such as supersonic airliners.*

THE DETAILS: Some conspiracy theorists suggest, with this question, that we don't goto the Moon because if we did it would become evident that we never went. Others claim that even today it would be technically impossible and therefore it was equally impossible in the 1960s. But there are also honest doubters who simply ask themselves why we don't repeat the fantastic voyage with today's far more modern technology.

The answer is disarmingly simple: putting astronauts on the Moon is very difficult, hugely expensive (at least for NASA's rather measly current budget) and extremely dangerous, and today there's no political motivation for spending massive amounts of public money and for risking human lives in the world's spotlight in this way. The disasters of Apollo 1, Soyuz 1 and 11, and of Shuttles *Challenger* and *Columbia* have shown all too clearly that the loss of a spacecraft crew is seen as a national tragedy and can be justified only if the stakes are tremendously high.

At the time of the Apollo flights, it was a national imperative to beat the Soviet regime and to rebuild the political and technological prestige of the United States. There's no such imperative today; there's no totalitarian enemy superpower to beat. In the 1960s, politicians funded the Moon landings with approximately 170 billion dollars (in current terms) and the lives of the astronauts were considered expendable for the sake of the nation. Thus many technical compromises were made which increased the chances of failure.

For example, Apollo 12 was launched *during a storm* and was struck twice by lightning, almost killing the crew (Figure 7.1-1). Taking such a risk today would be unthinkable: even uncrewed spacecraft are not launched if there's even a chance of bad weather.



Figure 7.1-1. Lightning strikes the Apollo 12 launch pad at liftoff. NASA photo S69-60068.

The lunar module had a single descent engine and a single engine for return from the Moon; likewise, the command and service module had to rely on a single engine. If any of these failed, the astronauts would die.

Crucial and delicate rendezvous maneuvers had to be performed in orbit around the Moon, instead of close to Earth, to reduce the launch weight of the spacecraft. But in this way, if the lunar module failed to meet the command module after landing on the Moon, no rescue was possible.

Every mission had its share of malfunctions and near failures. Apollo 13 even suffered a crippling oxygen tank explosion that forced to abort its lunar landing. If the explosion had occurred during return from the Moon instead of on the way out, when onboard reserves were still high and the lunar module was still available as a lifeboat, the outcome would have been fatal.

Today, NASA's budget is almost halved compared to the Apollo era: in 2010 dollars, the total sum of NASA budgets in the period from 1963 to 1969 was 209.2 billion; from 2003 to 2009 it was 113.1 billion. Moreover, the safety requirements are far more stringent and the loss of a crew is politically far less acceptable. This causes cost increases and slows the development of spacecraft qualified to carry a crew.

The race to beat the Soviets in space ended half a century ago, so space missions are carried out for science rather than for national pride, taking lower risks and using uncrewed spacecraft, which have achieved amazing scientific successes throughout the Solar System; crewed spaceflights

have been confined to Earth orbit, for example to assemble and visit the International Space Station.

Right now there is no political, technical or scientific reason that justifies the cost and risk of a crewed return to the Moon. Moreover, for the United States it would be a repeat.

It may seem absurd and implausible that in the 1960s we could do something that we can't do today, but there are other cases of journeys to remote places that were made once and not repeated for decades.

- Mankind first reached the South Pole in December 1911, with Roald Amundsen's team, followed a few weeks later by Robert Scott's men (who died on the return trip). After that, nobody set foot on the South Pole for all of 45 years, until US Rear Admiral George J. Dufek and his multinational crew landed there with an aircraft in October 1956.
- The Marianas Trench, the deepest point of all of the world's oceans, almost 11 kilometers (6.8 miles) below the surface, was reached for the first time in 1960 by Don Walsh and Jacques Piccard on board the bathyscaphe *Trieste*. Fifty-two years passed before anyone returned: director James Cameron went there solo in 2012 with the *Deepsea Challenger.*
- On 16 August 1960, US military pilot Joseph Kittinger became the first human being to jump with a parachute from the stratosphere, approximately 31.3 km (19.47 miles) above the Earth, as part of the *Excelsior* military project; his record remained unbeaten for 52 years, until Austrian Felix Baumgartner jumped from 39 km (24.2 miles) on 16 October 2012.

The apparent contradiction of past technology being superior to today's is explained by similar cases in other fields.

- In the 1970s we had supersonic airliners: the Anglo-French *Concorde*, shown in Figure 7.1-2, and the Russian Tupolev Tu-144. Today, for a wide range of reasons, we don't.
- Until July 2011, there was a spacecraft capable of taking seven astronauts and twenty tons of payload into Earth orbit and landing on a runway like a glider: the Space Shuttle (Russia had *Buran*, a very similar spacecraft, but it flew only once, uncrewed and without a payload, before the project was canceled). Not anymore: the Shuttle fleet has been retired after thirty years of service, and its current replacements are Soyuz capsules that land under a parachute and carry a maximum of three people, like Apollo did. Future Orion and Crew Dragon spacecraft will use the same configuration, albeit with bigger crews.

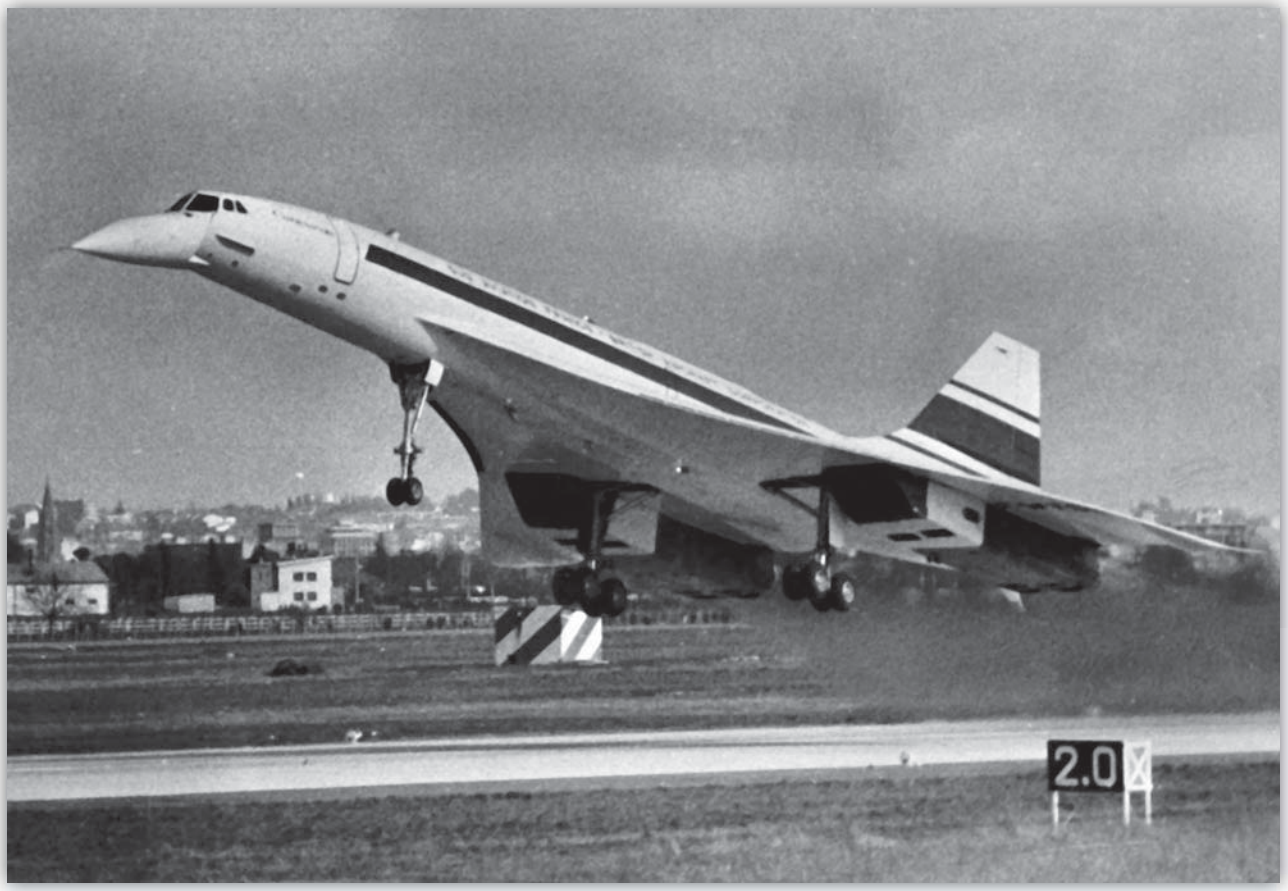


Figure 7.1-2. The first flight of the Anglo-French supersonic airliner Concorde *on 2 March 1969. Credit: André Cros.*

The reasons for these technological retreats are the same as for Apollo: excessively fragile technologies, no longer sustainable costs and no longer acceptable risk levels.

Anyone who argues that technology in the 1960s wasn't advanced enough to go to the Moon probably isn't very familiar with the period. For example, Figure 7.1-3 isn't a still from a science fiction movies: it's a photograph of a real US strategic bomber prototype, the XB-70, capable of flying at three times the speed of sound while riding its own shockwave, focused under its wings, to generate lift. It was already flying *five years before* the first Moon landing.



Figure 7.1-3. The first XB-70 Valkyrie. This plane was flying in 1964. Source: Ron Eisele.



Figure 7.1-4. An SR-71 seen from below. Source: Swedish Air Force/The Drive.

Another fine example: the SR-71 strategic reconnaissance aircraft (Figure 7.1-4), capable of flying at over 3,500 km/h (2,174 mph; its actual top speed is still classified) at an altitude of 26,000 meters (85,000 feet). This plane, like the XB-70, flew in 1964.

It's also worth mentioning the X-15 (Figure 7.1-5), a rocket-propelled aircraft that was carried by a modified B-52 bomber and was capable of reaching speeds of 7,200 km/h (4,400 mph) and altitudes of 108 kilometers (354,000 feet) and therefore flew beyond the atmosphere: its pilots therefore became astronauts. It debuted in 1959, ten years before the first Moon landing, and its pilots later included a young Neil Armstrong (he was 30 at the time). It took 44 years before anything like the X-15 reappeared: in 2004 the privately-funded spaceplane *SpaceShip One* reached 100 kilometers



Figure 7.1-5. An X-15 shortly after being released from the aircraft that carried it up to its initial altitude.

(32,800 feet), but did not attain the top speed reached by the X-15, which is still today the fastest ever crewed spaceplane.



Figure 7.1-6. Neil Armstrong poses with an X-15 in 1960 after a test flight. Source: NASA.

7.2 How come the Russians didn't even try? Did they know it was impossible?

IN A NUTSHELL: *Actually, they* did *try, and they tried hard, too. They actually had* two *separate Moon landing projects. But their giant N1 rockets, designed and built specifically for lunar missions, kept exploding during test launches. The projects were abandoned and kept secret to avoid international humiliation, as detailed in Chapter 1, but the cover-up was revealed when the Soviet Union collapsed.*

THE DETAILS: There actually *was* a Moon hoax, but not the one most space conspiracy theorists talk about: the Soviet one, meant to hide all evidence of their failed attempts to be the first to fly a crewed mission around the Moon and then achieve a crewed lunar landing.

The Soviet Union in fact embarked on not one, but *two* large lunar projects, named L1 and N1-L3 (there was also a third minor one, based on another giant rocket, the UR-700, which however did not get very far beyond the design stage). These were preceded by uncrewed flights such as *Zond 5*, which in 1968 flew living beings (turtles, wine flies, meal worms, plants, seeds and bacteria) around the Moon and returned them safely to Earth.

The secret Russian L1 fly-around project was based on two scenarios. In the first one, a Proton rocket would launch an L1 spacecraft (a stripped-down Soyuz) equipped with an additional Block D booster stage, flying directly to the Moon.

In the second scenario, the same type of Proton launcher would place an uncrewed L1 spacecraft and Block D stage in Earth orbit; a three-man crew would climb to Earth orbit using a second Soyuz on another rocket (probably an R-7). Two of the three cosmonauts would then transfer to the L1 spacecraft and accelerate to fly around the Moon, while the third crewmember would return to Earth.

This project was approved and funded by the Soviet authorities and spacecraft manufacturing was started, with the goal of a lunar fly-around by 1967, one year before the Americans. However, the fatal accident of Soyuz 1, which cost the life of cosmonaut Vladimir Komarov, and the reliability problems of the Proton launcher caused delays that allowed the American space program to achieve the first crewed flight around the Moon with Apollo 8 in 1968.

The Russians also had another secret project, the N1-L3 (Figures 7.2-1, 7.2-2 and 7.2-3), for landing a single cosmonaut on the Moon, as described in Chapter 1.

However, the expensive, complex and massive N1 launcher, designed not only to get to the Moon but (in a nuclear-powered version) to set up a permanent lunar base and fly to Mars, turned out to be dramatically unreliable. The first four test flights, between 1969 and 1971, were four disastrous failures, mainly caused by the challenge of managing so many engines (thirty in the first stage).

Moreover, Russia's brilliant and highly influential chief designer Sergei Korolev, who spearheaded the N1 project and had masterminded all of the Soviet Union's space achievements, died suddenly in 1966.

All this caused delays that gave the United States the time to perfect their technology and be the first to land a crew on the Moon.

Russia's last attempt at a lunar fly-around took place a few days before the Apollo 11 landing and failed when the N1 rocket that carried the uncrewed L1 spacecraft exploded catastrophically on the launch pad.

The Soviet conspiracy to hide all traces of these attempts and failures was quite successful, so much that even today many Moon hoax believers are blissfully unaware of this aspect of the space race. At the time, Russian authorities declared



Figure 7.2-1. Size comparison between the Saturn V-Apollo stack (left) and the Soviet N1-L3 system (right). The person at the bottom is to scale. Source: Ebs08, Wikimedia.

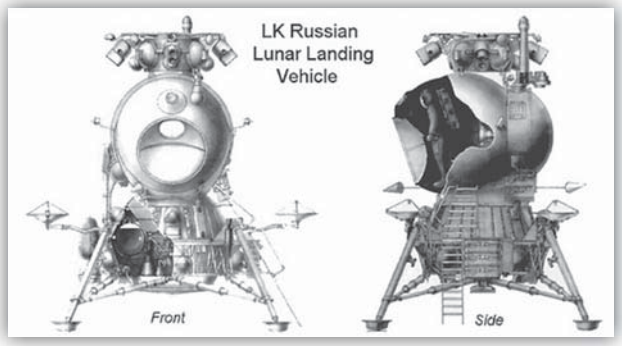


Figure 7.2-2. Schematic view of the Soviet lunar module. Credit: David Baker, Soyuz Owners' Workshop Manual*, Haynes (2014).*

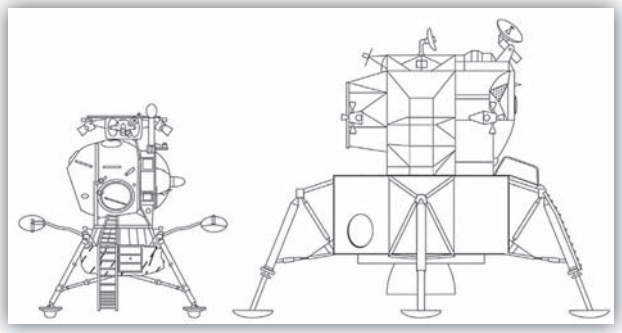


Figure 7.2-3. Size comparison between the Russian lunar module (left) and the US LM (right). Credit: David Baker, Soyuz Owners' Workshop Manual*, Haynes (2014).*

that they had never taken part in a race for the Moon, that they had no intention of taking a Russian to the Moon and that they would never risk a Soviet citizen's life on such a dangerous endeavor, which could be accomplished just as effectively with uncrewed vehicles. That was the official party line.

Rumors of the explosion of a large Soviet rocket surfaced in the Western press[1] and there were also unintentional news leaks: in 1981, Soviet spacecraft Kosmos 434, launched in 1971, fell back to Earth and crashed in Australia, and the Soviet authorities stated that it was an old *"lunar cabin prototype"*, the same term used to describe the American lunar module.

1 *Il vettore sovietico esploso: la NASA lo sapeva ("Exploded Soviet launcher: NASA knew")*, *Il Giorno*, 21 November 1969.

By and large, however, the Western media fell for the Soviet hoax. Even celebrated newsman Walter Cronkite stated on TV in 1974 that *"it turned out there never had been a race to the Moon"*.[2]

2 *Fifth Anniversary – Apollo in Retrospect*, CBS, July 1974, as quoted in *Cronkite on Space: Inspiration, not Information*, by James Oberg, in *Space Review*, 6 March 2006.

However, the surprising reality of the Russian attempts to land a man on the Moon, long suspected by Western experts and partly known to US intelligence, became very public with the collapse of the Soviet Union in the 1990s.

Soviet censors first allowed public disclosure of the N1 project in the summer of 1989, in a series of articles.[3]

3 *S zemli na lunu i obratno* [*From the Earth to the Moon and back*] by Lev Kamanin, in *Poisk* no. 12, July 1989; *Kak my ne sletali na lunu* [*How we didn't go to the Moon* by S. Leskov, in *Izvestiya*, 18 August 1989; *Polety vo sne i nayvu* [*Flights in fancy and in reality*], by A. Tarasov, in *Pravda*, 20 October 1989).

Today the Soviet Moonshots are described in details in several documentaries and by richly illustrated books such as the following:

- *Mishin Monograph on Failure of Soviet Manned Lunar Program*, in *JPRS Report*, 12 November 1991. Also available in French as *Pourquoi nous ne sommes pas allés sur la lune,* Vasily Mishin, Editions Cépaduès (1993).
- *Uncovering Soviet Disasters*, James E. Oberg (1988, pages 150-151).
- *Rockets and People*, Boris Chertok (2005; in particular the fourth volume).
- *N-1: For the Moon and Mars - A Reference Guide to the Soviet Superbooster*, Matthew Johnson and Nick Stevens with Alexander Shliadinsky, Igor Bezyaev, Vladimir Antipov, ARA Press (2013).
- *Russia in Space*, Anatoly Zak, Apogee Prime (2013).
- *Soyuz Owners' Workshop Manual*, David Baker, Haynes (2014).

Although the Soviet space program to reach the Moon with a crew was not successful, the fact that it existed (and the huge investments that it entailed, together with the

uncrewed reconnaissance and testing flights) disproves any argument claiming that the trip was considered technologically or physically impossible.



Figure 7.2-4. An excerpt from a Russian documentary covering the Soviet lunar plans. The N1 is discussed from 3:00 onwards [http://tiny.cc/nhrvdz].

7.3 Weren't 1960s computers too primitive?

IN A NUTSHELL: *No. The Apollo spacecraft's computer technology was certainly primitive compared to today's, but it was still adequate, also thanks to the presence of three very powerful additional "computers": the astronauts, who were all trained to control the spacecraft and calculate trajectories, orbits and rendezvous by hand if necessary. Moreover, most of the computing power wasn't on board: it was in NASA's much larger computers on Earth.*

THE DETAILS: Moon hoax theorists often point to the fact that a modern cellphone has more computing power and memory than the onboard computer of the Apollo spacecraft and argue, therefore, that it's unthinkable that anyone could have flown to the Moon with such limited equipment.

But first of all, the Saturn-Apollo spacecraft had *five* main onboard computers, not one:

- two Raytheon AGCs (*Apollo Guidance Computers*), one in the lunar module and one in the command module;
- one IBM-built LVDC (*Launch Vehicle Digital Computer*) in the Saturn's Instrument Unit;
- a Honeywell SCS (*Stabilization and Control System*) in the command module;
- and a TRW-designed AGS (*Abort Guidance System*) in the lunar module.

It's true that the onboard computing power of the Apollo spacecraft was puny compared to today's standards. For example, each one of the AGCs, designed by MIT's Instrumentation Laboratory under the supervision of Charles Draper, had the following specifications:

- 2K (2,048) words of rewritable memory (RAM), equivalent to approximately 3.7 kilobytes (AGC word length was 15 bits plus one parity bit), whereas a laptop computer currently has at least 16 gigabytes, i.e., *four million* times more;
- 36K (36,864) words of read-only memory (ROM), roughly equal to 76 kilobytes;
- a 1.024 megahertz clock, whereas current computer clocks run at 4 gigahertz or more, i.e., four thousand times faster. Yes, that's a decimal point, not a thousands separator.

It's not true, however, that the AGCs were less powerful than a pocket calculator, as is often claimed: their performance

was comparable to an Apple II (1977), a Commodore 64 (1982) or a ZX Spectrum (1982).

Moreover, the onboard computers could focus all their power on a small set of core tasks and didn't have to waste power on fancy graphical interfaces or other embellishments, so they were adequate for the tasks they had to perform.



Figure 7.3-1. The Real-Time Computer Complex (RTCC). Credit: IBM.

The onboard systems also had the backup of Mission Control's massive Real-Time Computer Complex in Houston, Texas, based on five IBM System/360 Model 75J mainframe computers, which handled most of the calculations (Figure 7.3-1).

Most of all, the Apollo spacecraft carried three astronauts, highly trained to control all the spacecraft's systems, to calculate trajectories, rendezvous and orbits using slide rules and precomputed charts, and to navigate using the stars. They acted, in a way, as additional computers, making up for the limitations of the automatic systems available at the time: consider, for example, the manual override decided on the spot by Neil Armstrong during Apollo 11 to avoid landing in an unexpected boulder field that the onboard and ground computers couldn't detect, or the manual realignment performed by James Lovell during Apollo 13 after the automatic navigation system had been shut down to conserve power after an oxygen tank failure crippled their ship.



Figure 7.3-2. The display and keyboard (DSKY) of an Apollo Guidance Computer (AGC).

In other words, the total available computing power wasn't as small as is often thought.

Anyone who wishes to get to know the actual specifications of the Apollo Guidance Computer or has doubts regarding their authenticity can refer to extremely detailed sites such as *Virtual AGC* (which allow to reconstruct a physical replica or to emulate an AGC on present-day computers) and to books such as *The Apollo Guidance Computer: Architecture and Operation* by Frank O'Brien (Springer Praxis, 2010).

The original software of this computer was published on Virtual AGC in 2003 and was distributed via Github in July 2016, so anyone can inspect it. Understanding it in detail obviously requires considerable IT skills; anyone who doesn't have this kind of knowledge can ask a trusted expert to check that the software is real and works.



Figure 7.3-3. Margaret Hamilton with a printout of the Apollo AGC software. Credit: NASA.

Faking these computers would have also entailed writing all this software: the size of such a task is clearly shown by Figure 7.3-3, which shows a full printout of the software next to Margaret Hamilton, who was the director of the software engineering at the MIT Instrumentation Laboratory for the Apollo program when she was 33 years old, at a time when all key jobs were assigned to men and discrimination against women was rampant.

Together with her team, Hamilton defined the design and testing criteria for the software that ran the onboard computer of the Lunar Module and developed the concepts of asynchronous flight software and priority scheduling which saved the Apollo computers from crashing during overloads such as the ones that occurred during the Apollo 11 descent to the Moon.

In 1986 Hamilton founded Hamilton Technologies, a company specialized in ultra-high-reliability software. As of 2020, she is still the CEO of the company. In 2003 NASA gave Hamilton the Exceptional Space Act Award, which included the largest cash reward ever given to a single person by the agency.

All the work done for Apollo was quickly transferred to everyday technology. The basic concepts of the AGC, for example, were not only included in the design of the Space Shuttle but also laid the foundations for today's assisted piloting technologies for military aircraft and airliners. The methods developed under Margaret Hamilton's supervision to go to the Moon spawned an industry which is currently worth approximately 400 billion dollars.

7.4 How is it possible that everything went so smoothly?

IN A NUTSHELL: *It didn't. NASA went out of its way to give this impression, but the truth was quite different. Three astronauts died on the launch pad (Apollo 1). Apollo 13 suffered an explosion that scrubbed its lunar landing and almost killed the crew. Apollo 12 was struck by lightning at liftoff. Apollo 11 had a computer overload as it was landing on the Moon and lost control during rendezvous. Every mission had its significant malfunctions, equipment failures and close calls, and many crews were struck by nausea, vomiting and diarrhea, but all this wasn't widely publicized.*

THE DETAILS: Moon hoax theorists often express their sarcastic amazement at the perfection of the Apollo flights to the Moon. How is it possible that such incredibly complex and powerful machines, which pushed the envelope of 1960s technology, could work so flawlessly? And how could astronauts be so impeccably cool and professional on such life-threatening journeys?

Actually, this perfection is only an impression driven by superficial knowledge of the events and by the fact that the political importance of the lunar missions prompted NASA and the media to gloss over the errors and failures and the less dignified aspects of the endeavor. National prestige was at stake, so problems were played down in public. Some failures, however, were too big to be brushed under the carpet.

As a matter of fact, out of seven attempted Moon landing missions, one failed (Apollo 13). Three astronauts died on the launch pad (White, Grissom and Chaffee, Apollo 1). All the missions had problems that brought the crew close to disaster or abort. Here are a few examples taken from the technical mission reports. A more extensive list of the various critical and non-critical malfunctions that affected the various missions is in the *Discrepancy Summary* section of the *Post-launch Mission Operation Reports*.

Apollo 7

- Water from the cooling systems pooled in the cabin, posing a serious danger in an environment crammed with electrical wiring.
- The crew was plagued by a cold that blocked their nasal passages: a serious problem in spaceflight, because in weightlessness fluid accumulates instead of draining and blowing one's nose can cause severe ear pain, and because during reentry, with their head enclosed in the helmet, the astronauts would be unable to clear their ears and therefore compensate for cabin pressure changes, with the risk of eardrum damage. Despite

NASA's strong disagreement, the crew performed reentry without wearing their helmets and suffered no physical consequences.

- The Apollo 7 crew also refused orders from Mission Control, and commander Walter Schirra had no uncertain words about the unprecedented workload of the maiden flight of the Apollo spacecraft, speaking openly of *"tests that were ill prepared and hastily conceived by an idiot"* and declaring that he'd *"had it up to here"* and that his crew was *"not going to accept any new games... or going to do some crazy tests we never heard of before"*, as described in the book *Apollo: the Epic Journey to the Moon*, by David Reynolds. This was one of several underreported rebellions of spaceflight crews.

Apollo 8

- The first crewed flight around the Moon was troubled by bouts of vomiting and diarrhea affecting the mission commander, Frank Borman, during the first day of flight, nearly forcing an early return home.
- Three of the five spacecraft windows were fogged by sealant leaks, hindering viewing and lunar photography.
- Water again formed dangerous pools in the cabin, just like on Apollo 7.
- During the flight, Jim Lovell accidentally erased part of the computer's memory, leading the inertial position measurement unit (IMU) to assume that the spacecraft was still on the launch pad and to automatically ignite the maneuvering thrusters to try to correct the problem. The crew was forced to compute and reenter the correct data by hand.

Apollo 9

- Astronaut Rusty Schweickart vomited repeatedly due to nausea induced by weightlessness, forcing cancellation of the emergency procedure test (a spacewalk from the Lunar Module to the Command Module) and of the test of the lunar EVA spacesuit that he was scheduled to perform.
- One of the maneuvering thruster sets of the command and service module failed due to a misplaced switch.
- The Lunar Module tracking light failed: this was a crucial component, since the LM and the CSM had to maneuver and fly separately, up to 185 kilometers (115 miles) apart, in Earth orbit and then find each other and dock again, otherwise the two crewmembers in the LM would have died in orbit, unable to return to Earth. Rendezvous was achieved despite these failures thanks to the skill of the astronauts.

Apollo 10

- When the ascent stage of the LM separated from the descent stage, just 14.45 kilometers (47,400 feet) above the lunar surface, an incorrect switch setting made the spacecraft spin wildly about two axes, coming dangerously to a so-called *gimbal lock* (loss of orientation of the navigation system). Astronaut Gene Cernan let slip a heartfelt *"Son of a bitch!"*, which was picked up by his open radio mike and transmitted live to world audiences back on Earth.

Apollo 11

- During this first Moon landing, the Lunar Module's computer, which was crucial for a soft touchdown, overloaded repeatedly.
- The preprogrammed flight path for landing on the Moon would have taken the spacecraft to a boulder-strewn area, where landing and liftoff would have been prohibitive if not impossible. Only Armstrong's manual intervention to change landing site, assisted by Aldrin, saved the mission.
- As Armstrong and Aldrin descended to the Moon, the Lunar Module's descent engine experienced extreme fluctuations due to the instability of the control software. The landing was almost aborted, as explained in detail in *Tales from the Lunar Guidance Computer* by Don Eyles.
- Radio communications in lunar orbit, after separation of the LM from the Command Module, were so poor and broken up that Armstrong and Aldrin in the LM didn't hear the *"go"* to initiate descent to the Moon from Mission Control. Fortunately it was picked up by Michael Collins, in the Command Module, who relayed it to his colleagues.
- After landing on the Moon, one of the propellant lines of the descent stage failed to vent correctly due to freezing, leading to a potentially explosive pressure buildup. Only Mission Control noticed the problem and was discussing it guardedly with the crew when it cleared itself up by thawing.
- After the moonwalk, the astronauts realized that the knob of a circuit breaker required for arming the ascent engine was broken, probably because it had been struck by Aldrin's backpack. If that circuit could not be operated, liftoff from the Moon would be impossible. Complicated workarounds were possible, but the astronauts improvised by using a felt-tipped pen to operate the failed breaker.
- On returning from the lunar surface, when the LM docked with the command and service module, the slightly incorrect alignment of the two spacecraft

triggered an uncontrolled rotation that the onboard computers both tried to correct, contrasting each other and worsening the spin. Only Collins and Armstrong's skills allowed to correct manually the chaotic tumbling of the mated vehicles.

Apollo 12

- The lightning bolt that struck the Saturn V during liftoff caused widespread instrument malfunctions and a total loss of meaningful telemetry. Only an unusual suggestion by John Aaron in Mission Control (the request to set *"SCE to AUX"*), radioed up to the astronauts, allowed them to restore telemetry and prevented the mission from being aborted immediately.
- During the live TV broadcast from the Moon, the TV camera was pointed accidentally at the sun and its delicate sensor burned out, ending TV transmissions for the mission's moonwalk.
- At the end of the flight, during atmospheric reentry, the wind caused the command module to swing beneath its parachutes and the astronauts were subjected to 15 g of deceleration on impact; a camera fell from its holder and struck Alan Bean on his temple. Had it fallen slightly to the left, it would have caused a potentially fatal head trauma.

Apollo 13

- As already mentioned, an oxygen tank in the service module ruptured explosively, depriving the astronauts of air and power reserves. It became necessary to use the LM as a lifeboat and return hurriedly to Earth after looping around the Moon. James Lovell had to align the navigation systems manually by star sighting.

Apollo 14

- On the way to the Moon, the docking mechanism between the LM and the Command Module failed *five times* before finally working. This meant that it might fail again when the LM returned from the Moon, forcing the astronauts to perform a dangerous spacewalk to transfer from the LM to the Command Module, but the decision was made to go ahead with the landing nonetheless.
- An errant solder ball in the LM's general abort button caused the onboard computer to receive a false abort signal, which during lunar descent could have triggered an unnecessary emergency climb back to orbit, canceling the Moon landing: in the nick of time, NASA and MIT managed to write and send up instructions to reprogram the computer so that it would ignore the false signal.

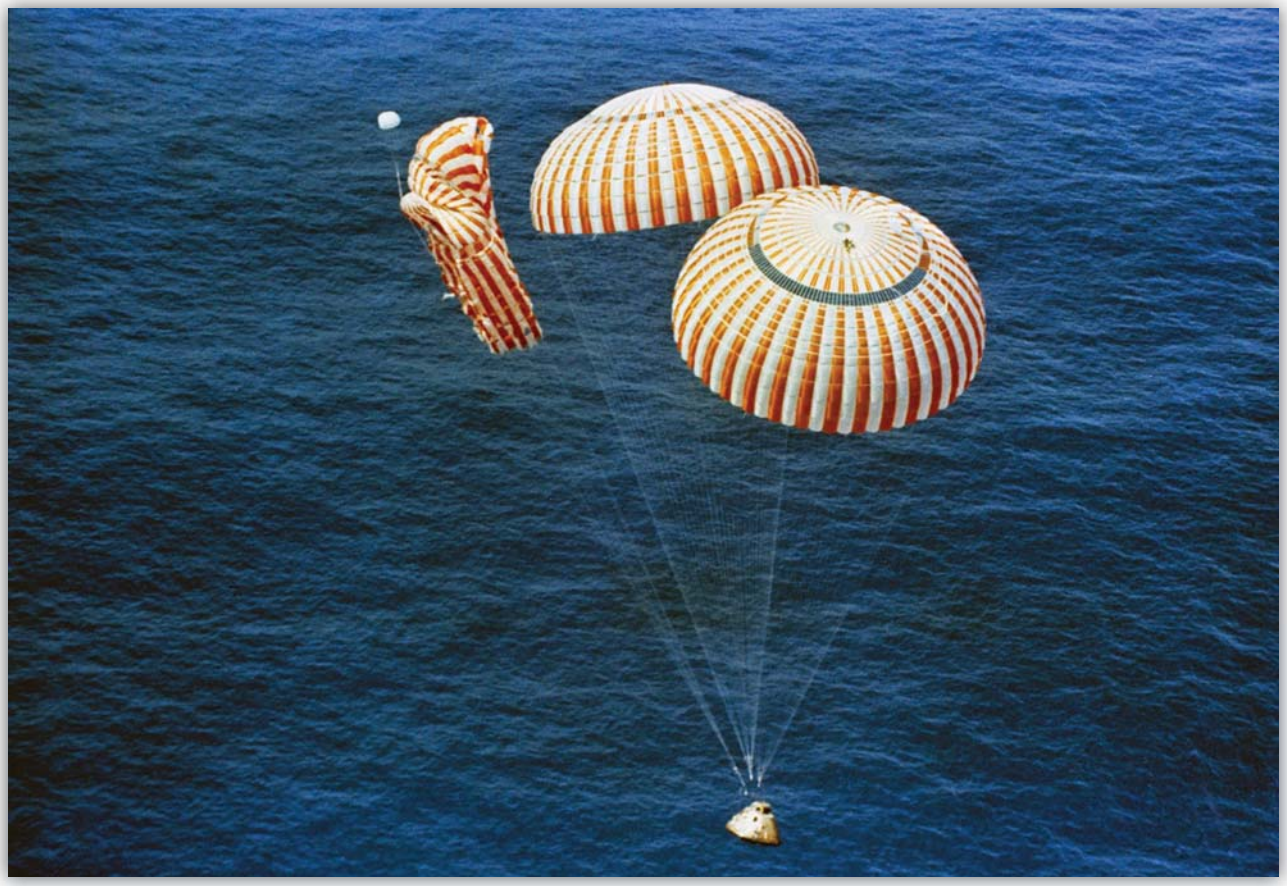


Figure 7.4-1. Apollo 15's splashdown with a malfunctioning parachute. Photo AS15-S71-42217.

Apollo 15

- One of the three splashdown parachutes failed to open fully (Figure 7.4-1), leading to a violent impact with the ocean. The malfunction was probably caused by venting propellants, which could have caused all three parachutes to fail, with fatal consequences for the crew.

Apollo 16

- The command and service module main engine, crucial for returning to Earth, reported a malfunction while the spacecraft was in orbit around the Moon. The Moon landing was almost scrubbed.

Apollo 17

- On the Moon, one of the astronauts unintentionally broke one of the fenders of the Rover electric car (LRV) and the moondust kicked up by the wheels fell copiously onto the vehicle, causing mechanical and thermal problems. The astronauts were forced to improvise repairs on the lunar surface.
- During ascent from the Moon, Mission Control lost radio contact with the Lunar Module and received no telemetry for four full minutes. The Conmand Module pilot had to repeat everything that the LM astronauts wanted to report to Earth.

7.5 Why do a rendezvous in lunar orbit, which makes no sense?

IN A NUTSHELL: *Actually, it does. Lunar rendezvous was chosen despite its dangers because it reduced drastically the fuel and payload requirements. It's riskier than doing it in Earth orbit, or avoiding it completely by landing directly on the Moon with a single spacecraft instead of using a two-part vehicle, but these alternatives would have required a truly gigantic rocket, far bigger than the already massive Saturn V.*

THE DETAILS: Some Moon hoax believers find it preposterous that NASA chose to perform intricate undockings, redockings and rendezvous between the Command Module and the Lunar Module, and to perform them near the Moon instead of in Earth orbit, which offered better chances of rescue if anything went wrong. Better still, why not follow the classic method featured in so many science fiction movies and land directly on the Moon with the main spacecraft, without using a separate lunar module?

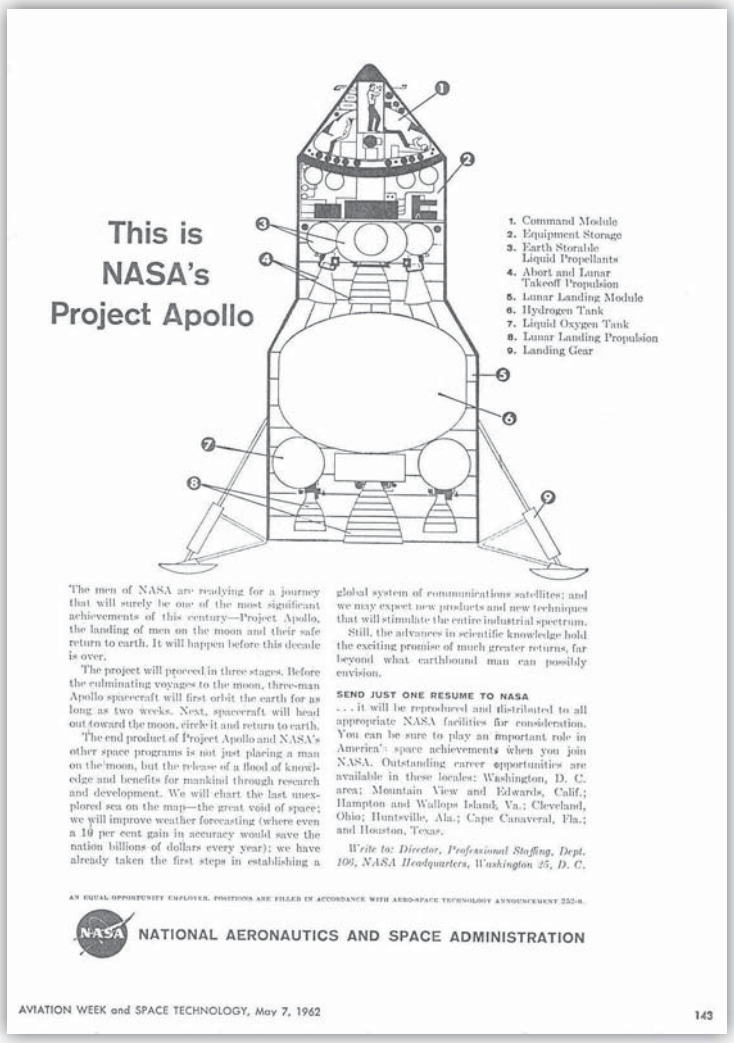


Figure 7.5-1. One configuration of thel tailsitter conceived initially as a lunar landing vehicle, in a NASA advert in the magazine Aviation Week and Space Technology*, May 1962. Source: Sven Knudson, Ninfinger.org.*

Actually, NASA's initial plan was indeed to land on the Moon with a single, large, tall spacecraft: a concept known as *tailsitter*, since it would land on its tail (Figure 7.5-1).

This solution had the advantage of requiring a relatively simple trajectory: a direct flight to the Moon (known as *direct ascent*), with no complicated maneuvers for docking and extracting a lunar module, no need for part of the crew to transfer to the landing module and no rendezvous in lunar orbit that might go wrong upon returning from the lunar surface. For all these reasons it was the favorite plan among the NASA engineers in charge of developing the various spacecraft for the Apollo project.

However, a tailsitter had some very substantial drawbacks: for example, the astronauts would be required to land a very tall and therefore unstable vehicle (it was approximately 20 meters, or 60 feet, tall in the version shown

in Figure 7.5-1). They would also have to land it without being able to see the lunar surface below them, due to the bulk of the spacecraft below them. In some versions they would have to resort to a periscope and fly while lying on their backs.

Once they had landed, they would have to climb down from the top of the spacecraft; not an easy feat in a rigid and bulky spacesuit, with the additional danger of falling (a fall on the Moon can be as fatal as on Earth, despite the lower gravity). Getting back in and loading the rock samples would entail a hazardous climb.

The main objection to a tailsitter was the fact that landing on the Moon with the entire spacecraft used for the trip from Earth, instead of using a dedicated bare-bones vehicle, would increase the mass involved, and therefore the fuel required, leading to the need for a rocket that was even larger than the already gigantic Saturn V.

For example, a tailsitter mission would require taking down to the lunar surface the entire crew and all the mass of the heat shield (useless on the Moon but necessary for return to Earth), as well as all the fuel, oxygen, water and food to be used on the return trip. This would require more powerful braking and descent engines, which would require more fuel, which in turn would require more powerful engines. All this mass, not needed on the Moon, would have to be lifted back from the lunar surface, requiring even more powerful ascent engines, and so forth.

Taking all the mass of a tailsitter on a direct flight to the Moon would have required a colossal rocket, the Nova (Figure 7.5-2), which didn't exist yet and could not be completed in time for President Kennedy's deadline. The only booster that could be developed in time was the Saturn V, which was relatively smaller.



Figure 7.5-2. The giant Nova booster (right) compared with the C-5, precursor of the Saturn V (center). Document M-MS-G-36-62, April 1962.

Mission planners also considered using a first Saturn V to launch an uncrewed tailsitter spacecraft into Earth orbit, followed by a second Saturn with the fuel. This was known as *Earth Orbit Rendezvous* (EOR) and was NASA's favored plan for some time. However, it entailed two closely coordinated launches and a dangerous and untested transfer of fuel in space. It also required landing on the Moon, and especially lifting off from the Moon, with no external help, a spacecraft as large as an Atlas rocket, which on Earth needed roughly three thousand people to prepare it for launch.

An alternative option was to split the tailsitter into two separate vehicles: the main one would remain in orbit

around the Moon and the secondary one would be a stripped-down, specialized Moon lander.

This approach reduced weight and fuel requirements so much (by about three quarters) that it allowed to launch the entire mission with a single Saturn V rocket. However, the savings came at the cost of a risky rendezvous in lunar orbit (hence the name *Lunar Orbit Rendezvous* or *LOR*), which entailed certain death for the moonwalkers if it failed. A high-stakes gamble, in other words, but a perfectly logical one.

The lunar orbit rendezvous plan wasn't new: it had been conceived in 1916 by Russian spaceflight theoretician Yuri Vasilievich Kondratyuk. Nevertheless, NASA was very reluctant to take this perilous and untested path, although preliminary studies on various methods, including LOR, had been ordered. The agency continued to believe that it had to try the tailsitter method. It should be remembered that at that time nobody had ever performed a rendezvous with docking in space, even in Earth orbit, and therefore the concept of performing a rendezvous while orbiting the Moon was extremely daring.

In 1961, a relatively low-ranking aerospace engineer at NASA, John Houbolt (1919-2014, Figure 7.5-3), vociferous supporter of the LOR method, skipped official channels and wrote an impassioned letter to NASA's associate administrator, Robert C. Seamans Jr., noting that he was *"a voice in the desert"* in arguing for the convenience, and indeed the need, to resort to this solution in order to meet the end-of-decade deadline.

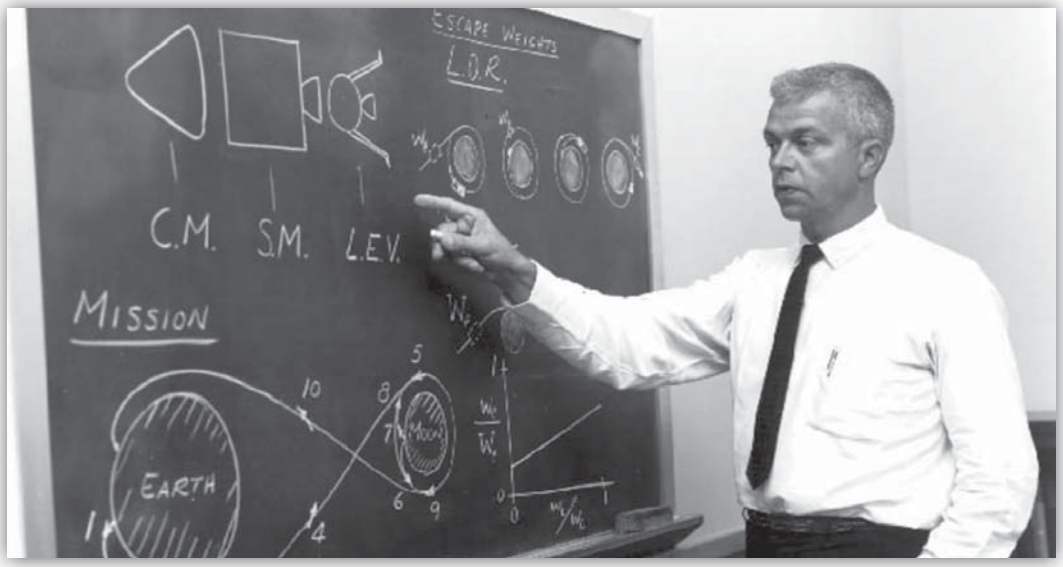


Figure 7.5-3. John Houbolt in 1962. Source: NASA/LARC/Bob Nye.

His initiative led to a review of the LOR concept, which however was not not backed by NASA senior managers. But Houbolt's persistence paid off: in July 1962 the obsession of

an unknown engineer became NASA's final plan for getting to the Moon.

John Houbolt's crucial role in the success of the Apollo missions is often unknown to non-experts, but NASA celebrates him extensively. Here are some references if you want to know more about him:

- *John C. Houbolt, Unsung Hero of the Apollo Program, Dies at Age 95* (NASA, 2014)
- *John C. Houbolt* (NASA, 2015)
- *The Rendezvous That Almost Wasn't* (NASA, 2004)
- *SP-4308 Spaceflight Revolution* by James R. Hansen (NASA, 1994)

7.6 Why don't we just point a telescope at the landing sites?

IN A NUTSHELL: *Because even the most powerful telescopes currently available on Earth can't see such small features so far away. Telescopes are designed to see objects that are enormously distant but also enormously large, like stars or galaxies, not Lunar Modules. Trigonometry and the laws of optics dictate that seeing any detail of the vehicles and equipment left at the Apollo landing sites from Earth would require a telescope with a mirror at least 45 meters (150 feet) in diameter. No current ground-based telescope comes even close.*

THE DETAILS: The *resolution* of a telescope, i.e., the detail that it can see at a given distance, is determined by the laws of optics, specifically by a formula known as *Dawes' limit*, and depends essentially on the diameter of the main lens or mirror. The bigger the diameter, the higher the resolution. Adding a lens to magnify the image acquired by this main telescope component will not yield more detail – only more blur.

The largest objects left on the Moon by the Apollo astronauts are the descent stages of the lunar modules, which measure approximately 9 meters (30 feet) across diagonally opposite footpads. A little trigonometry shows that at the minimum Earth-Moon distance, which is about 355,000 kilometers (220,600 miles), seeing a descent stage is equivalent to seeing a US one-cent coin from 740 kilometers (460 miles) away.

No current earthbound telescope can do that; not even the Hubble Space Telescope (Figure 7.6-1), which at the distance of the Moon can resolve nothing smaller than about 80 meters (262 feet).

That's an apparently counterintuitive fact. After all, telescopes can see incredibly distant galaxies, so why can't they get a good picture of a 9-meter (30-foot) object on the Moon, which is in our back yard, astronomically speaking?

The reason is that galaxies are enormous, while the Apollo objects on the Moon are tiny, and their closeness doesn't compensate for the massive difference in size.

For example, the Andromeda galaxy is two million light years (19 million million million kilometers or 12 million million million miles) from Earth, yet it's bigger than the full Moon in our night sky; it's hard to see with the naked eye because it's very faint. That's why large astronomical telescopes are designed more to collect light from these remote objects than to magnify them.

Dawes' limit[4] dictates that even in ideal conditions, seeing the Apollo Lunar Module descent stages on the Moon from Earth as nothing more than a bright dot would require a telescope with a primary lens or mirror at least 45 meters (150 feet) wide. Resolving any details of the spacecraft would require even more colossal telescopes.

The largest single-mirror telescopes on Earth are currently just over ten meters (33 feet) in diameter. Even the future record holder, the aptly-named Extremely Large Telescope, which is scheduled for completion in 2024, will be inadequate, because its composite primary mirror will only span 39 meters (130 feet).

Moreover, even if a sufficiently colossal telescope were built, its very size would lead to another problem: it would gather so much light that it would be dazzled.

In theory, such a hypothetical telescope could be used during a new Moon, when the Earth-facing side of the Moon is in darkness except for *earthshine*, i.e., the sunlight that reflects off the daylit portion of the Earth. However, the difference in brightness between the lunar surface and the Lunar Module would be minimal and there would be no significant shadow to provide depth and detail. Any images would be barely intelligible.

4 The resolution (or *resolving power*) of a telescope, in arcseconds, is 11.6 / diameter of the main lens in centimeters (or 4.56 / diameter of the main lens in inches). This formula does not take into account the performance penalty entailed by Earth's atmosphere. The *angular diameter* of an object, expressed in arcseconds, is calculated by means of the formula *(object size / distance) x 206,265*. The base of the Lunar Modules on the Moon, seen from Earth, has an angular diameter of 0.0052 arcseconds. The Hubble Space Telescope has a resolution of 0.05 arcseconds.



Figure 7.6-1. The Hubble Space Telescope, photographed from space in 1997 during mission STS-82 of the Shuttle Discovery, has a primary mirror with a diameter of 2.4 meters (7 feet 10.5 inches). Source: NASA.

Another approach might be a technique known as *interferometry*, which allows astronomers to pair two telescopes to obtain a sort of "virtual" instrument that has a resolution equal to a single telescope with a primary mirror as large as the distance between the two paired telescopes. The Very Large Telescope in Chile, one of the best-equipped observatories for this kind of science, in ideal conditions could achieve a resolution of 0.002 arcseconds: enough to show a LM on the Moon as a handful of pixels (dots forming a digital image). That sounds promising, but there's a catch.

Interferometry doesn't produce directly viewable images, but only *interference patterns*, which require computer processing to extract meaningful information. This means that there's no way to put a Moon hoax theorist in front of a massive telescope and tell him or her to peer into the eyepiece to see the Apollo landing sites in any significant detail.

In other words, we don't just point a giant telescope at the Moon because it would be useless.

However, it is quite possible to take a telescope closer to the Moon, point it at the Apollo landing sites and view them with enough detail to make out the Apollo spacecraft. This is what several space probes of various countries have done, as detailed in Section 7.7.

7.7 How come nobody sends probes to take pictures of the landing sites?

IN A NUTSHELL: *Actually, several countries have done just that. India, China, Japan and the United States,* have *sent science probes to the Moon and have surveyed its entire surface, including the Apollo landing sites. Their images confirm that there are vehicles and science instruments exactly where NASA said it placed them.*

THE DETAILS: Over the course of the decades since the Apollo crewed landings, the Moon has been visited and mapped in progressively greater detail by uncrewed probes sent by China, India, Japan and the United States. Some of these spacecraft are currently in operation in orbit around the Moon, sending fresh images and science data.

Many of these spacecraft carried telescopes and cameras, but these instruments were not powerful enough to show directly the vehicles left behind by the Apollo astronauts. However, they were able to acquire evidence of their presence. Three probes of three separate countries have photographed the differently-colored patch of lunar soil produced by the landing of Apollo 15. The Lunar Reconnaissance Orbiter was the first probe equipped with instruments that were capable of directly imaging in detail the Apollo vehicles.

Clementine (United States, 1994)

The 1994 Clementine probe, launched by NASA, spent 71 days orbiting the Moon to map its surface at various wavelengths, from ultraviolet to near infrared, and with a laser altimeter. The images acquired by this probe included the one shown in Figure 7.7-1, which features a dark patch of differently reflective soil exactly where NASA said that Apollo 15's LM had landed. This patch is compatible with the soil color changes expected as a consequence of the displacement of surface dust and the exposure of differently-colored underlying rock that would be caused by a spacecraft rocket motor.

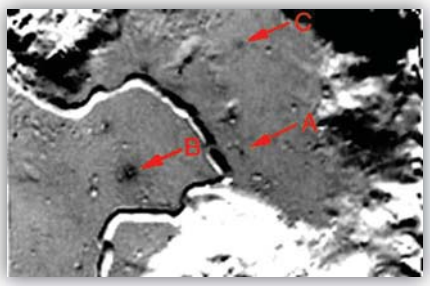


Figure 7.7-1. The dark patch marked by the letter A is located exactly where Apollo 15 landed. B and C are broader patches, probably caused by meteor impacts. This image was acquired using non-visible wavelengths and therefore the shades of gray do not necessarily match visible-light colors.

The Apollo 15 dust displacement was discovered in 2001 by Misha Kreslavsky of the department of geological sciences at Brown University (Rhode Island, United States) and by Yuri Shkuratov of the Kharkov Astronomical Observatory in Ukraine while they were studying lunar surface color changes produced by recent meteor impacts, which displace the soil.[5]

5 *Apollo 15 Landing Site Spotted in Images*, by Leonard David, Space.com, 27 aprile 2001.

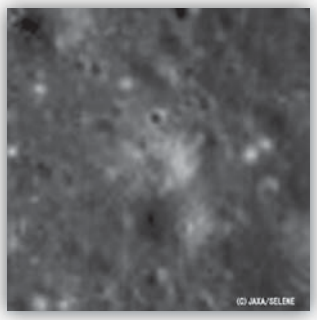


Figure 7.7-2. This visible-light image, published on 20 May 2008, shows a brighter patch right where Apollo 15 landed. Credit: JAXA/Selene.

Kàguya/SELENE (Japan, 2007-2009)

As it explored the Moon from orbit at an altitude of approximately 100 kilometers (62 miles), the Japanese probe Kaguya detected a differently-colored patch of lunar soil exactly where NASA said that Apollo 15 had landed (Figure 7.7-2). This finding, like Clementine's, is compatible with the color changes expected due to dust displacement by a landing rocket motor.

The Kaguya probe also acquired very accurate terrain contour maps of the landing sites, which exactly match the terrain shown in the Apollo photos, as described in Chapter 3.

Chandrayaan-1 (India, 2008-2009)

The Indian probe Chandrayaan-1 orbited around the Moon about 3400 times at an altitude of 100 kilometers (62 miles) to perform a chemical, mineralogical and geological survey. It carried scientific instruments from India, the United States, the United Kingdom, Germany, Sweden and Bulgaria.

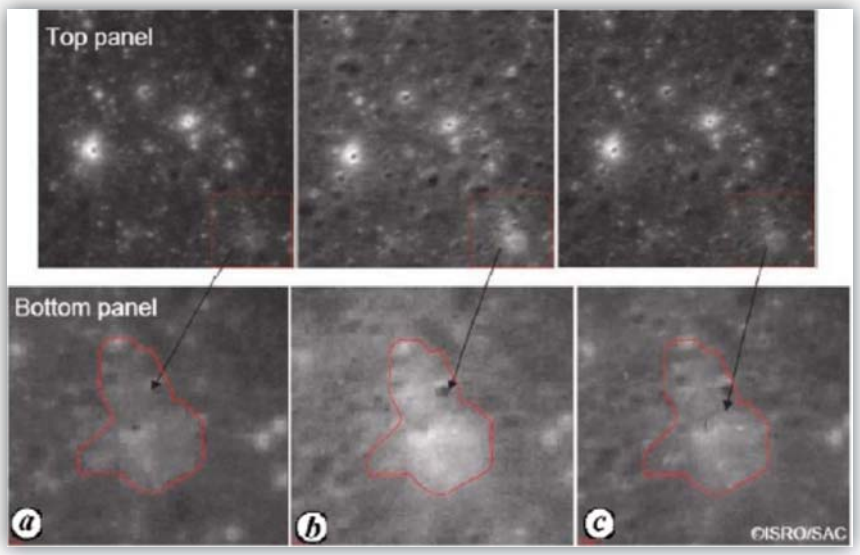


Figure 7.7-3. Images of the Apollo 15 landing site acquired by the three cameras of the Indian Chandrayaan-1 probe on 9 January 2009 (a = rear camera; b = nadir camera; c = front camera). Source: Chandrayaan-1 captures Halo around Apollo-15 landing site using stereoscopic views from Terrain Mapping Camera *by Prakash Chauhan, Ajai and A.S.; Kirankumar, in* Current Science *vol. 97, no. 5, 10 September 2009, p. 630-31.*

Like Clementine and Kaguya, Chandrayaan-1 acquired images showing a brighter patch at the Apollo 15 landing site, but it did better than its predecessors: it detected a faint dot at the location of the descent stage of the Lunar Module (Figure 7.7-3).

Lunar Reconnaissance Orbiter (USA, 2009-)

The United States' Lunar Reconnaissance Orbiter (LRO) probe was the first spacecraft equipped with instruments capable of directly imaging the Apollo vehicles left on the Moon. It achieved this result as part of its ongoing lunar mapping mission.

Its first images of the Apollo landing sites were published on 17 July 2009 and some of them are shown in Chapter 3.

Chang'e-2 (China, 2010-2011)

China has sent several probes to the Moon. In 2010, its Chang'e-2 spacecraft mapped the Moon from an altitude which varied between 15 and 100 kilometers (9.3 and 62 miles), with a maximum resolution of 7 meters (23 feet). According to a statement made in 2012 by Yan Jun, chief application scientist of the Chinese lunar exploration program, Chang'e-2 *"spotted traces of the previous Apollo mission in the images"*. However, the imagery has not been released.

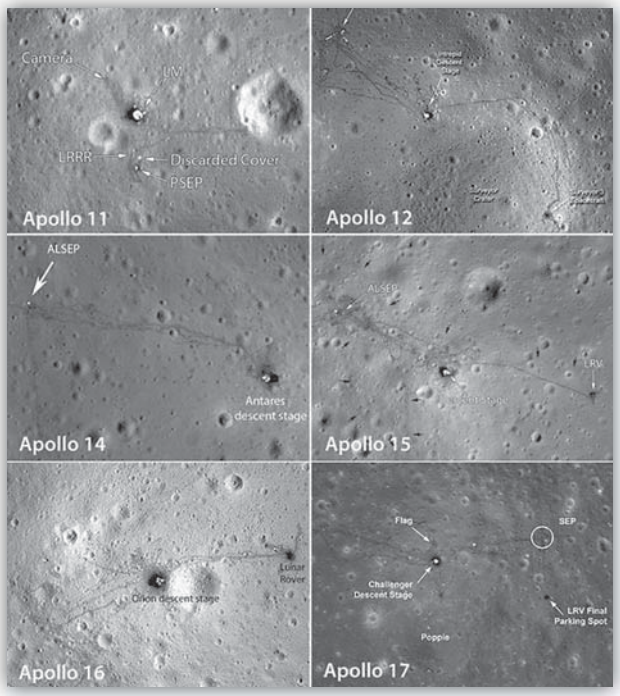


Figure 7.7-4. Images of the six Apollo landing sites acquired by the Lunar Reconnaissance Orbiter (2009-).

Images of Apollo hardware crash sites on the Moon

In addition to the actual landing sites, there are other traces of these missions on the Moon. The ascent stages of the Lunar Modules of Apollo 12, 14, 15, 16 and 17, and the third stages of Apollo 13, 14, 15, 16 and 17 were deliberately crashed on the Moon. Many of these crash sites have been imaged from orbit by the Lunar Reconnaissance Orbiter, showing patterns of debris that support NASA's claims.[6]

6 *Spacecraft Impacts on the Moon: Chang'e 1, Apollo LM Ascent Stages* in *Lunar and Planetary Science* XLVIII (2017); *Impact Sites of Apollo LM Ascent and SIVB Stages*, NASA; *The Crash Site of Apollo 16's Rocket Booster Has Been Spotted on The Moon*, Sciencealert.com (2015).

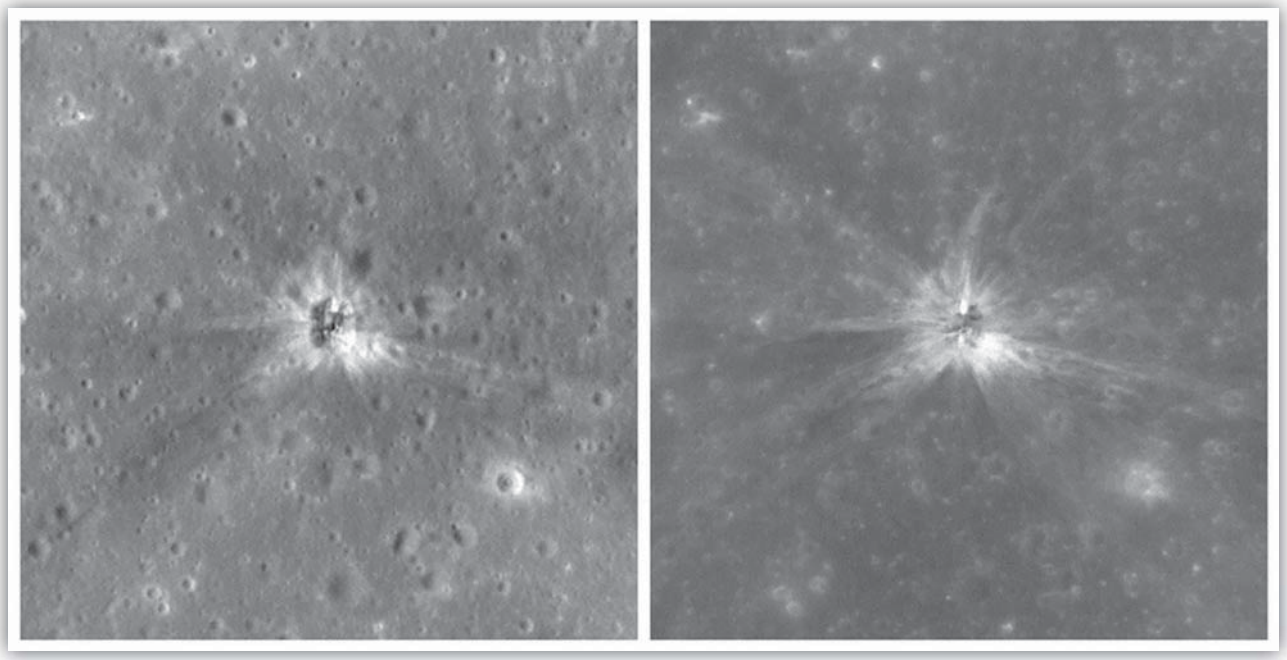


Figure 7.7-5. Images of the Apollo 16 third stage crash site on the Moon. Credit: NASA/Goddard/Arizona State University. Source: Space.com.

7.8 How could the large Moon buggy fit inside the small Lunar Module?

IN A NUTSHELL: *It was folded up inside the Lunar Module's descent stage.*

THE DETAILS: Many people compare the sizes of the Lunar Roving Vehicle or Rover (the electric car used by Apollo 15, 16 and 17) and of the Lunar Module and wonder how the Rover could fit inside the LM.

The Rover was 2.96 meters (116.5 inches) long, 2.06 meters (81 inches) wide and 1.14 meters (44.8 inches) tall and at first glance seems to be incompatible with the dimensions of the lunar module, whose descent stage was about 4.3 meters (14.1 feet) wide without including the legs and also had to accommodate the descent rocket engine and its fuel.



Figure 7.8-1. The Apollo 16 Rover at first glance seems too large to be carried inside the Lunar Module. Photo AS16-107-17436.

The answer is quite simple: the LRV was designed to fold up for transport so that it would fit in one of the wedge-shaped recesses provided in the descent stage structure (Figure 7.8-2).

The Rover was also far simpler than an ordinary car: it was little more than an aluminum chassis with four small electric motors for the wheels and two motors for steering, a battery pack and two tube-frame seats. On Earth it weighed about 200 kilograms (440 pounds).

Being an electric car, it required no gearbox or shift, no transmission shaft and no wheel axles. The wheels were coupled directly to the motors. This allowed it to fold up very compactly (Figures 7.8-3-4-5-6).

The TV footage of the lunar excursions shows very clearly how the Rover was extracted and deployed to assume its unfolded configuration for use.

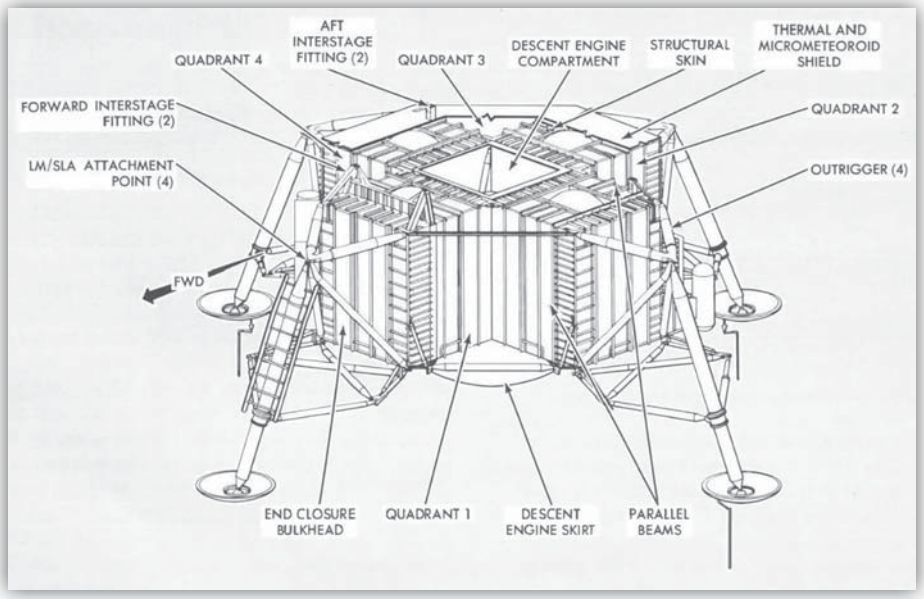


Figure 7.8-2. Schematic view of the internal structure of the Lunar Module descent stage. One of the four available recesses is at the center. This is the recess that would accommodate a Rover during Apollo 15, 16, and 17. Source: Apollo News Reference - Lunar Module - Quick Reference Data.

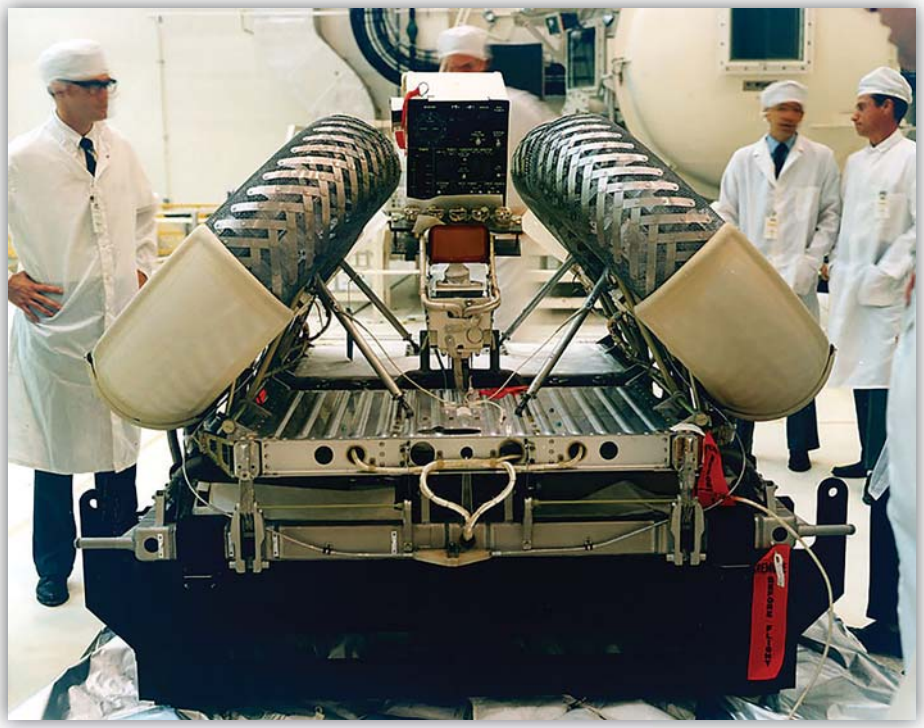
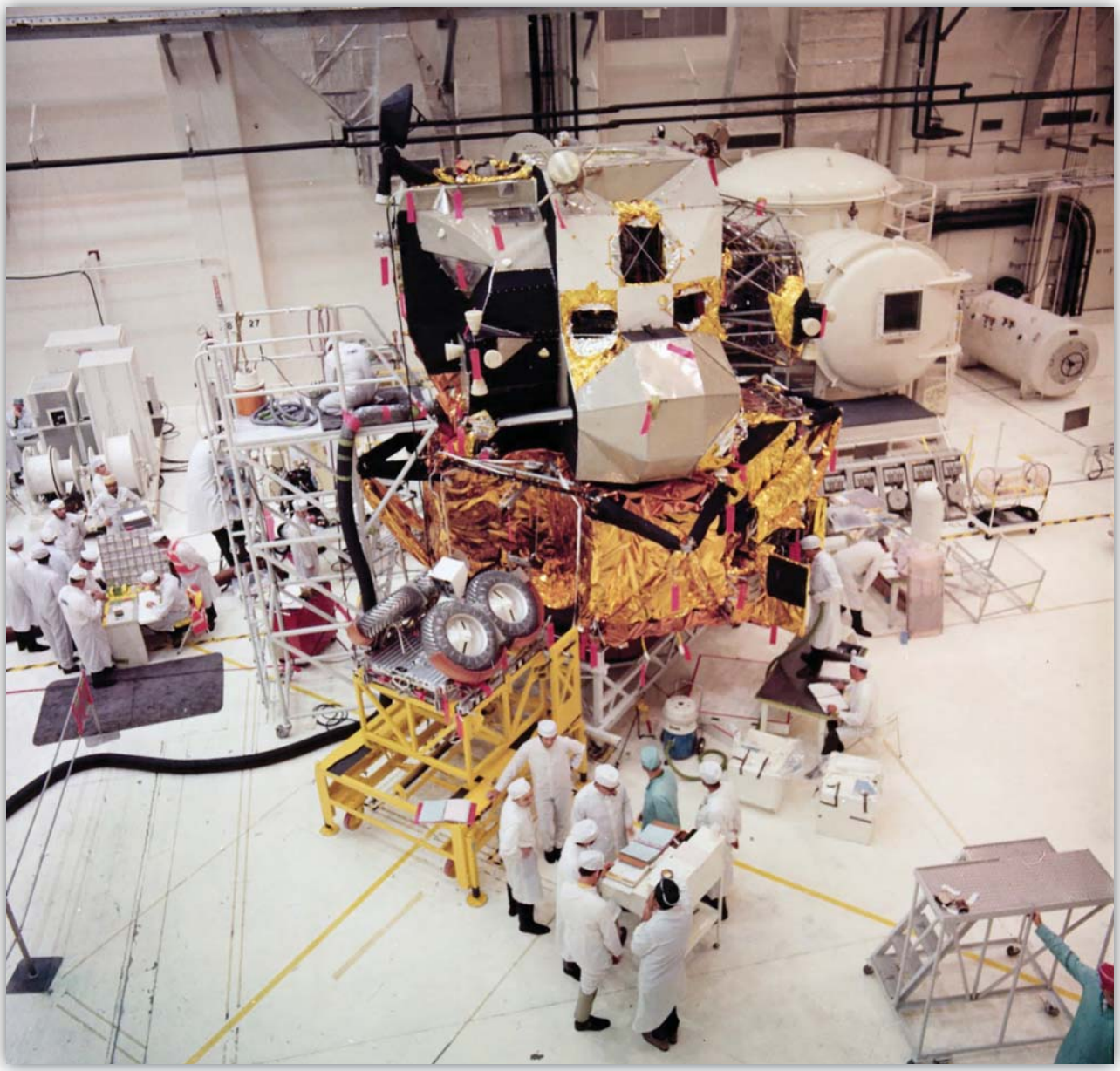
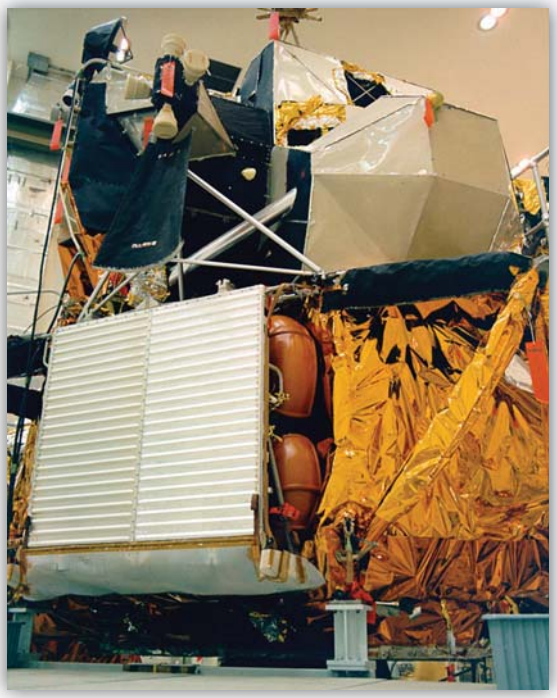


Figure 7.8-3. The Apollo 15 Rover in its folded configuration. Photo AP15-KSC-71PC-224.



Above: Figure 7.8-4. The Apollo 15 Rover, folded to assume a wedge-like shape, is ready to be loaded into its receptacle in the Lunar Module descent stage. Photo AP15-71-HC-684.



On the right: Figure 7.8-5. The Apollo 15 Rover in its receptacle. Photo AP15-KSC-71PC-415.



Figure 7.8-6. The folded Apollo 15 Rover can be glimpsed in the upper right part of this detail of photo AS15-91-12331, taken in space on the way to the Moon.



Figure 7.8-7. Animation of the Rover deployment procedure [http://tiny.cc/rwsvdz].



Figure 7.8-8. The live TV broadcast (sped up for brevity) of the Apollo 15 Rover deployment. Credit: Amy Shira Teitel [http://tiny.cc/i0svdz].



Figure 7.8-9. Animation of the Rover folding process. Credit: Don McMillan [http://tiny.cc/i6svdz].

7.9 How could Apollo get to the Moon, if it didn't reach escape velocity?

IN A NUTSHELL: *Because it didn't need to. Getting to the Moon doesn't require escape velocity: a spacecraft only has to achieve a speed that produces a highly elongated orbit around the Earth that reaches a maximum altitude equal to the distance of the Moon, without ever escaping from the Earth's pull.*

THE DETAILS: This pro-conspiracy argument is a fine example of the misuse of science jargon and factual data to give an impression of competence and knowledge.

Its premise is formally correct:

- The *escape velocity*, the speed required to escape the Earth's gravity field, is 11.2 kilometers per second (about 7 miles per second), i.e., 40,320 kilometers per hour (about 25,000 mph), at ground level.
- However, NASA reported (for example in the Apollo 11 press kit, page 30) that the top speed of Apollo 11 during its climb to the Moon, at the end of the firing of the S-IVB stage for TLI (Trans-Lunar Injection), was about 39,000 kilometers per hour (about 24,250 mph).
- In other words, Apollo 11's stated maximum speed was about 1,230 kilometers per hour (765 mph) slower than escape velocity.

So, the argument goes, how could the Apollo spacecraft escape Earth and reach the Moon?

The answer to this apparent contradiction is that escape velocity is required only if the spacecraft seeks to escape Earth's attraction *permanently*. Anything traveling at this velocity will never fall back to Earth and will continue to climb away from it indefinitely without requiring any additional thrust (more specifically, it will escape from Earth's gravity field yet will still be in the grip of the Sun's gravitational attraction).

However, the Apollo lunar flights had no need to achieve this result. On the contrary, the astronauts were really keen to return home. So NASA used a different solution.

A spacecraft doesn't actually need to reach escape velocity to get to the Moon. It just has to achieve a speed that produces an elliptical orbit around the Earth that stretches out to the distance of the Moon and is timed so that the Moon is at the opposite end of the ellipse when the spacecraft gets there. So the Apollo flights didn't have to reach escape velocity to land on the Moon or fly around it.

Actually, staying below escape velocity is a safety bonus, because it allows to use a so-called *free return* trajectory (Figure 7.9-1): the spacecraft will fall back to Earth spontaneously, without requiring additional maneuvers or thrust from its rocket motors.

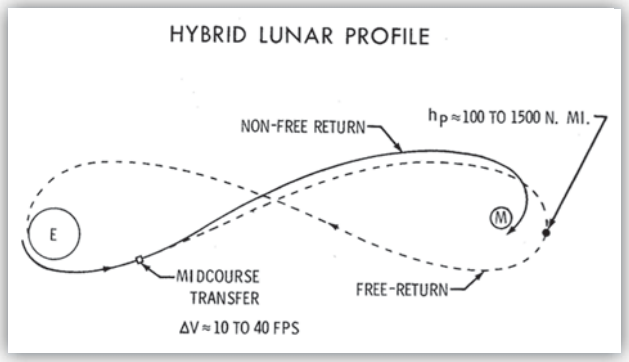


Figure 7.9-1. The main trajectories used by the Apollo missions. From the Apollo 11 Press Kit.

This is particularly useful in case of major malfunctions, as in the case of Apollo 13. More specifically, Apollo 13 began its flight on a free return trajectory and then fired its main engine to leave this trajectory and fly towards the Moon. After the onboard explosion, the thrust of the LM's descent engine was used to inject the astronauts into another free return trajectory.

7.10 Do Russian calculations show that the Saturn V wasn't powerful enough?

IN A NUTSHELL: *No. The mathematical analysis of the Saturn V liftoff footage published by Stanislav Pokrovsky estimates the power of the first stage, but the trip to the Moon depended on the power of the* third *stage.*

THE DETAILS: A complex, math-heavy analysis[7] published in Russian by Stanislav Pokrovsky argues that the actual speed of the Saturn V Moon rocket when it exhausted the fuel of its first stage and separated from the rest of the spacecraft was only half of the speed claimed by official documents.

Pokrovsky claims that the F-1 engines of the Saturn's first stage were not powerful enough to carry to the Moon the 46-ton payload constituted by the Command and Service Module and the Lunar Module. His calculations suggest that the low speed entailed that the maximum payload that could be delivered to the Moon by a Saturn V was approximately 28 tons. Since the CSM weighed over 30,000 kilograms (66,000 pounds) and the LM weighed over 15,000 kilograms (33,000 pounds), Pokrovsky argues that NASA could fly one or the other, but not both, to the Moon, and therefore the best it could achieve was a flight around the Moon, without landing.

However, despite the impressive charts and formulas, this analysis has a fundamental flaw. Pokrovski's calculations and estimates relate only to the Saturn V's *first* stage. But this stage, together with the second stage, only had the task of placing the third stage and the Apollo spacecraft into Earth orbit (with some help from the third stage). The first two stages did not contribute to the actual trip from Earth orbit to the Moon, which was instead powered by the *third* stage.

Since Pokrovsky acknowledges that Earth orbit was achieved by the Saturn V's first two stages with its full 46-ton payload of Apollo vehicles (otherwise the first stage would not have lifted off so slowly as Pokrovsky himself argues), all his remarks and calculations regarding the actual or alleged speed of the first stage are simply irrelevant in terms of how many tons of payload could be sent to the Moon.

In the laws of physics that govern orbital flight, what matters is the *final* speed of a spacecraft, which must be sufficient to stay in orbit without falling back to Earth. The speed *during* the climb to altitude is only relevant in terms of fuel consumption and crew comfort: a faster climb uses less fuel, but subjects the astronauts to higher acceleration stresses (up to 4.7 g for the Saturn V just before first stage separation; Gemini's Titan launchers reached 7 g). In principle, a slow climb to orbital altitude followed

7 *УТОЧНЕННАЯ ОЦЕНКА СКОРОСТИ САТУРНА-5*, Supernovum.ru, 2014; available in English as *Investigation into the Saturn V velocity and its ability to place the stated payload into lunar orbit* at Aulis.com. In the English version, Pokrovsky is described as a *"Ph.D," "Candidate of Technical Sciences"* and *"General Director of scientific-manufacturing enterprise Project-D-MSK"*.

by acceleration to orbital speed would still achieve orbit. Therefore Pokrovsky's issue of first stage speed is irrelevant.

Moreover, Pokrovsky's argument is based on an estimate of the progressive apparent distance between the Saturn V and the exhaust plume of the first-stage retrorockets; an estimate made purely by examining blurry footage from one of NASA's tracking cameras (Figure 7.10-1). It is quite hard to measure the exact point where a rocket plume ends.

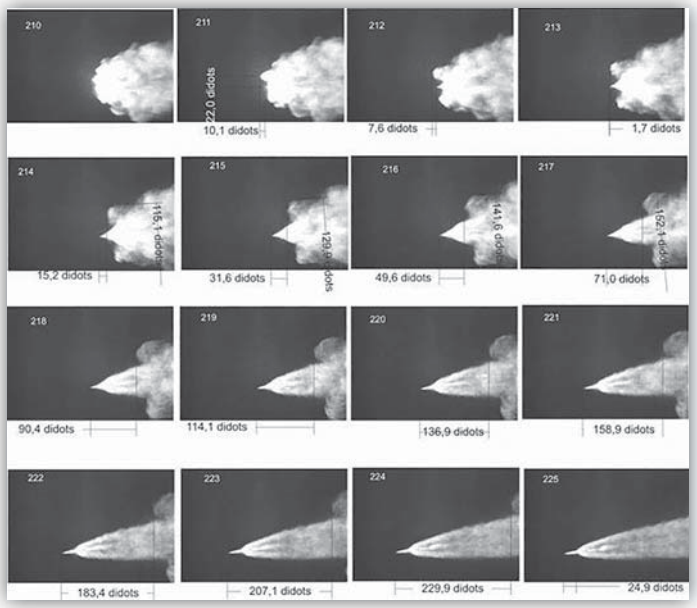


Figure 7.10-1. The low-resolution frames of the liftoff footage analyzed by Pokrovsky.

Moreover, Pokrovsky assumes that the retrorocket plume somehow stopped in mid-air, instantaneously losing the tremendous speed of the spacecraft that generated it, and therefore can be used as a fixed reference point to calculate the speed of the Saturn V rocket. But the first stage separated from the rest of the spacecraft (Figure 7-11) at an altitude of over 61,000 meters (200,000 feet), where the atmosphere is approximately 10,000 times thinner that at sea level, so there was no significant air resistance to slow the plume or stop it. Presumably, by inertia this plume would continue to climb, chasing the rocket and thus biasing any visual estimate of distance and speed.



Figure 7.10-2. Separation of the first stage of the Saturn V during the Apollo 11 flight. Detail from NASA photo S69-39958.

7.11 How could the tiny LM climb back from the Moon?

IN A NUTSHELL: *It didn't have to fight against air resistance, it only had to cope with one sixth of Earth's gravity, and it only had to reach one quarter of the orbital speed required to orbit the Earth. The fuel demands of a lunar liftoff are far lower than terrestrial ones and the payload was minimal (two astronauts, some Moon rocks and a tiny, ultralight spacecraft). Also, the LM only had to achieve lunar* orbit*, not lunar escape velocity, since the thrust for the trip back to Earth was provided by the Service Module's main engine.*

THE DETAILS: The truly minuscule size and fragile appearance of the LM's ascent stage used to return from the Moon (Figure 7.11-1) are a striking contrast to the colossal size of the Saturn V required to leave Earth. Some people doubt that such a tiny spacecraft could be adequate and wonder, for example, where all the fuel needed to climb and accelerate to escape velocity from the Moon (8,568 km/h or 5,323 mph) could be stored.



Figure 7.11-1. The Apollo 16 LM ascent stage returns from the Moon. Detail from photo AS16-122-19530.

Actually, the comparison is quite misleading, because it would be harder to find two more dissimilar liftoffs. The Saturn V had to lift its own huge initial mass of approximately 2,900 tons against Earth's gravity and against air resistance (aerodynamic drag) up to a speed of 28,000 kilometers per hour (about 17,400 miles per hour) and inject a 130-ton payload into Earth orbit, at an altitude of 190 kilometers (118 miles).

The LM's ascent stage instead had to lift an initial mass of 4.5 tons (of which 2.3 were fuel, leading to a very large loss of mass during the climb as the fuel was used) and accelerate it to approximately 6,600 kilometers per hour (4,100 miles per hour), raising a payload of 2.2 tons to a maximum altitude of 83 kilometers (approximately 51 miles). Moreover, on the airless Moon there was no atmospheric drag and the gravity was one sixth of the Earth's.

The idea of having to reach escape velocity is also wrong: as mentioned in Section 7.9, escape velocity is required only to fly away indefinitely from a celestial body without further fuel consumption. But the LM didn't need to do that: it only had to reach a speed that allowed it to enter an elliptical orbit with a minimum altitude of 16.6 kilometers (10.3 miles) and a maximum altitude of 83 kilometers (about 51 miles).

The extra thrust required to leave lunar orbit and fly back to Earth was provided by the rocket engine of the Service

Module, which stayed in lunar orbit indeed to avoid landing and bringing back up additional mass. NASA's choice of a lunar rendezvous was made for this very reason: to achieve great mass and fuel savings.

All these factors drastically reduce the power requirements of a lunar liftoff, so approximately 2,350 kilograms (5,181 pounds) of fuel, constituted by 910 kilograms (2,006 pounds) of Aerozine 50 and 1,440 kilograms (3,175 pounds) of dinitrogen tetroxide, were sufficient to lift the stripped-down ascent stage into a low lunar orbit.

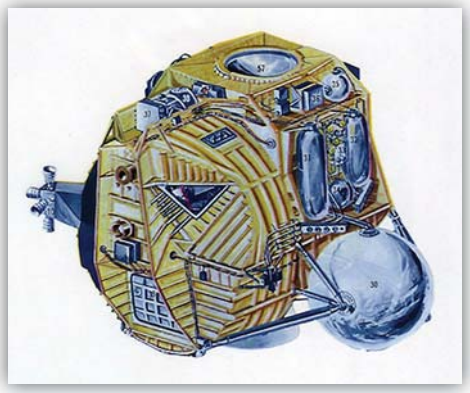


Figure 7.11-2. A cutout drawing of the LM ascent stage published by Grumman.

That may sound like a lot of fuel to store in such a small spacecraft, but these substances have a density of 0.903 g/cm^3 and 1.443 g/cm^3 (56.372 and 90.083 lb/ft^3) respectively, and therefore the quantities reported by NASA have a volume of approximately 1 cubic meter (35.3 cubic feet) each, which fits quite adequately in the two spherical tanks located in the bulges at the opposite sides of the cylindrical crew compartment of the ascent stage. Figure 7.11-2 shows the Aerozine 50 tank.

7.12 How could the Lunar Module be so stable?

IN A NUTSHELL: *Because appearances are misleading. The irregular shape of the LM, with its odd bulges and single central rocket motor, seems strangely top-heavy and as unstable as a football balanced on a finger, ready to tip sideways at the slightest wobble: apparently impossible to fly. But if you look under the skin and explore the LM's internal structure and bear in mind that it flew in the vacuum of space, it turns out that it was actually easier to stabilize than a conventional pencil-shaped rocket, because its main masses were located at or below the center of thrust of the motor and therefore its center of mass was quite low.*

THE DETAILS: Moon hoax theorist Bart Sibrel claims that the Apollo lunar module had a high center of mass that made it too unstable to fly.

Sibrel is not an aerospace specialist, yet he appears to believe that he can judge the stability of a spacecraft just by looking at its pictures. Actually, a less superficial examination based on some elementary physics reveals that the LM was *easier* to stabilize than a conventional rocket.

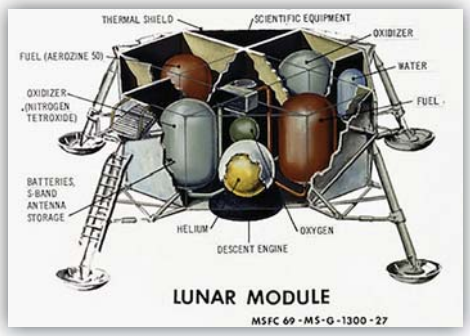


Figure 7.12-1. Arrangement of the fuel tanks in the LM descent stage.

In the descent stage and in the ascent stage, the fuel tanks, which are the most important masses of the vehicle, were located as low as possible, laterally with respect to the motor (Figure 7.12-1).

This is a far more stable configuration than a conventional rocket, in which the tanks (and therefore their great masses) are located above the engines. Placing these tanks laterally and at opposite ends actually helped to stabilize the vehicle, somewhat like the pole of a tightrope walker.

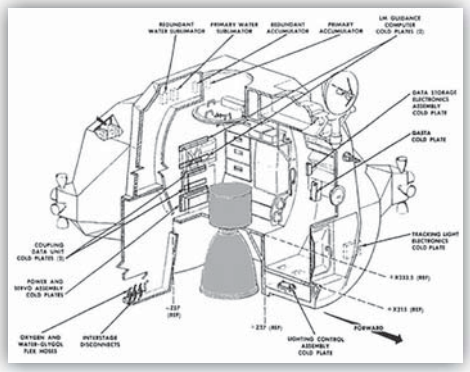


Figure 7.12-2. Cross-section of the LM ascent stage: the main rocket motor is shaded. Source: Apollo Operations Handbook*, volume 1, with added shading.*

Moreover, the main engines were not underneath the spacecraft, as a cursory inspection of the LM might suggest, but were deep inside it, with only the nozzle protruding below. The ascent stage's engine was actually inside the crew compartment (Figure 7.12-2). This meant that the *center of thrust* (the imaginary point, located at the top of the nozzle, on which a vehicle "rests" when its engine is on) was close to the center of mass, which was an ideal situation in terms of stability.

Finally, the sixteen maneuvering thrusters were placed at the end of outriggers, as far as possible from the thrust axis of the main engine, so as to augment their effectiveness in a lever-like fashion.

The asymmetrical shape of the lunar module was actually dictated by the choice to balance it: in the ascent stage, for example, the dinitrogen tetroxide tank was placed closer to the engine thrust axis than the tank that stored the Aerozine 50 because this fuel component is considerably lighter than dinitrogen tetroxide for an equal volume.

To a layperson, the squat shape of the LM may seem unstable because it's so different from the slender shape of traditional rockets. But traditional rockets fly in an atmosphere and therefore are subject to complex aerodynamic rules which govern their stability: specifically, they have a *center of pressure* that must be kept below their center of mass, otherwise they become unstable.[8] As a result, all other conditions being equal, a slender vehicle is more stable than a squat one *in an atmosphere*. But the LM flew in a vacuum and therefore was not constrained by any aerodynamic rules (it had no center of pressure to manage) and this simplified its stability.

8 *Rocket Stability Condition*, Nasa.gov.

7.13 How come the astronauts didn't unbalance the tiny LM?

IN A NUTSHELL: *Because they were close to the center of the spacecraft and so their movements had a very small effect, which was compensated automatically by the onboard computers.*

THE DETAILS: In Fox TV's *Did We Land on the Moon?*, Ralph Rene alleges that the movements of the astronauts in the cabin of the Lunar Module would have shifted the center of mass continually and therefore would have caused the spacecraft to tip over uncontrollably and crash. Therefore, he argues, the LM could not fly and accordingly the Moon landings are fake.

The facts are quite different. First of all, the LM had not one, but two automatic stabilization systems that controlled the maneuvering thrusters (the ones clustered at the end of the ascent stage's outriggers) to compensate constantly for any imbalance. The astronauts didn't stabilize the spacecraft manually. The computer-controlled stabilization can be noticed in the liftoff footage, which shows a characteristic periodic oscillation induced by the automatic firing of the thrusters as soon as an imbalance was detected.

The concept is not at all unusual today and wasn't in the 1960s: any rocket has the same problem of compensating for shifts in the center of mass (for example due to fuel displacement or depletion). In the atmosphere, fins can be used; in space, gimbaled main engines and small maneuvering thrusters are used. This is a solution shared by all spacecraft of all countries, including the Space Shuttle and SpaceX's Falcon rockets.

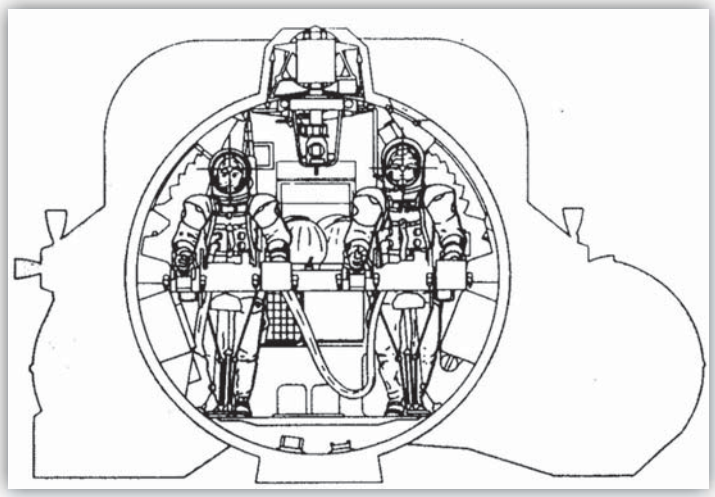


Figure 7.13-1. The position of the astronauts in the LM during flight. The main engine is between them; the fuel tanks are at the opposite sides of the outline. Detail of Figure 1-6 of the Apollo Operations Handbook - Lunar Module LM10 and Subsequent*.*

Secondly, the astronauts stood very close to the center of mass of the lunar module and didn't have much room to move anyway (Figure 7.13-1).

Moreover, the astronauts weighed far less than the twofuel tanks, which had a mass of 910 and 1,440 kilograms (2,006 and 3,175 pounds) respectively. The crew's movements, therefore, couldn't affect the balance of the spacecraft to any great extent. The main challenge to stability was the sloshing of the fuel in the tanks as they gradually emptied, but this was handled by the computer-based stabilization systems.

7.14 How come the LM simulator was so unstable that Neil Armstrong crashed it?

IN A NUTSHELL: *Because it was completely different from the Lunar Module. Anyway, Neil Armstrong's crash was caused by a rare malfunction of the vehicle, not by his inability to control it. The simulator had flown normally over 790 times without loss of control.*

THE DETAILS: Some conspiracy theorists claim that a few weeks before the Apollo 11 flight, one of the vehicles that simulated the Lunar Module's flight on Earth crashed and almost killed Neil Armstrong, who had lost control of the vehicle (Figure 7.14-1). Therefore, they argue, the actual Lunar Module was unstable beyond control and NASA could not have solved such a severe problem in such short time.



Figure 7.14-1. Neil Armstrong parachutes to safety after the malfunction of his LLRV.

First of all, the simulators were completely different from the Lunar Module and therefore any problem in the simulator had no effect on the stability or reliability of the LM.

The Apollo astronauts familiarized with Moon landings and with the unique characteristics of the Lunar Module by using two types of flying simulator, known as *Lunar Landing Research Vehicle* (LLRV) and *Lunar Landing Training Vehicle* (LLTV). Two LLRVs were built initially, followed by three LLTVs. All were single-seaters.

These were essentially bare frames on which a gimbaled jet engine was mounted vertically, so that its thrust supported five sixths of the weight of the ungainly craft. The remainder (the weight it would have had on the Moon) was supported by two throttleable rocket engines. Figure 7.14-2 shows clearly how different these vehicles were with respect to the actual Lunar Module.



Figure 7.14-2. An LLRV in flight in 1964. Detail from NASA photo ECN-506.

Like the LM, these vehicles had sixteen small thrusters for attitude control: one of the few things they actually shared with the spacecraft that they had to simulate. An electronic system kept the main jet engine constantly vertical and adjusted its thrust so as to simulate the effects of the reduced vertical acceleration that occurs on the Moon. Flights lasted only a handful of minutes, but were long enough to practice landing from an altitude of approximately 1,200 meters (4,000 feet).

Armstrong's accident occurred on May 6, 1968: not a few weeks before his Moon landing, but *fourteen months earlier.* Moreover, it was not caused by inherent instability problems of the vehicle (an LLRV): the pressurization system of the attitude thrusters failed, a gust of wind caught the vehicle, and Armstrong had no choice but to eject, landing safely under his parachute while the LLRV crashed and burned.

Conspiracy theorists make it sound as if crashing was the normal conclusion of the flights of these vehicles, but in actual fact the five simulators that were built flew a total of 792 flights with successful landings. Armstrong's LLRV had flown without mishap 281 times before the crash. During the training program, these experimental vehicles suffered just two more accidents, in December 1968 and in January 1971, leading to their destruction. The pilots were unharmed.[9]

For example, Figure 7.14-3 is a video of a 1969 flight of the LLRV which ended with a smooth landing. Neil Armstrong was at the controls.

9 *Unconventional, Contrary, and Ugly: The Lunar Landing Research Vehicle*, by Gene J. Matranga, C. Wayne Ottinger and Calvin R. Jarvis with C. Christian Gelzer. NASA SP-2004-4535 (2005), p. 142.



Figure 7.14-3. Neil Armstrong flies the LLRV without mishap in 1969. Source: NASA Armstrong Flight Research Center [http://tiny.cc/kpuvdz].

7.15 How come all the technical problems suddenly vanished?

IN A NUTSHELL: *They didn't. Problems occurred throughout all the missions and the first uncrewed flights were designed, as usual, to shake down the vehicles and correct or reduce their defects before the actual crewed missions were flown.*

THE DETAILS: A recurring argument among hoax theorists is that the early Apollo missions were plagued with problems, leading to very public delays and cancellations, but all the troubles magically disappeared just in time for the flights to the Moon.

For example, Mary Bennett and David Percy claim that "[the Saturn V] *performed flawlessly throughout the entire Apollo program. But the early Saturn V F-1 engine tests were absolutely disastrous, with catastrophic explosions on the test stand."* They add that *"The problem of combustion instability* [...] *known as the 'pogo effect' (the industry term for those internal oscillations we mentioned earlier) was in evidence from early testing of the Saturn rocket right through to the 'Apollo 10' launch – after which everything worked perfectly!"* And Bill Kaysing asked *"Why was Apollo 6, a total fiasco, followed by six perfect moon missions which in turn were followed by the manned orbiting lab debacle?"*[10]

10 Mary Bennett and David Percy, *Dark Moon*, p. 127-128; Bill Kaysing, *We Never Went to the Moon*, p. 8. The *"manned orbiting lab"* is Skylab.

Actually, if you check these claims against the mission reports, it turns out that the Saturn V's performance wasn't *"flawless"* at all. It always got the job done, but nearly all flights reported substantial problems.

Far from working *"perfectly"* after Apollo 10, as Bennett and Percy claim, the Saturn V was troubled by the pogo effect during Apollo 11 and 12 as well, leading to violent vibrations of the central F-1 engine of the first stage. For Apollo 13, vibrations were so intense that the central J-2 engine of the second stage had to be shut down automatically during ascent to Earth orbit to prevent it from tearing the spacecraft to pieces. Changes made for Apollo 14 finally made the problem manageable. Section 7.4 of this chapter covers in detail the major malfunctions and problems that affected all the Apollo missions.

As regards the *"catastrophic explosions on the test stand,"* that's why rocket designers have tests and use test stands: to iron out the worst kinks before actual flights. Indeed, celebrated Russian designer Boris Chertok noted repeatedly, in his monumental book series *Rockets and People*, that one of the key reasons for the failure of the Soviet moonshot attempts was the unwise decision to avoid building a full-scale test firing rig for the giant N1 rocket, opting instead to test the engines directly in a series



Figure 7.15-1. Liftoff of AS-203 (known informally as "Apollo 2").

of uncrewed flights. This decision led to four consecutive catastrophic failures of the N1, after which the project was scrubbed and buried.

The successful performance of the Saturn V was the result of extensive testing not only on the ground, but also in flight. There's a reason why the first actual crewed Apollo flight, after the Apollo 1 fire that killed Grissom, White and Chaffee on the pad during a test, was number 7: all the previous ones were uncrewed test launches.

Flight AS-203, launched on 5 July 1966 (Figure 7.15-1), used a Saturn IB first stage to carry and test the S-IVB, which would become the third stage of the Saturn V.

Flight AS-202, on 25 August 1966, flew the Command and Service Modules, testing the Apollo heat shield at reentry speeds similar to those expected for a return from the Moon and also qualifying the Saturn IB for crewed flights.

Apollo 4 was the first flight of the giant Saturn V rocket (no flight was ever formally designated Apollo 2 or 3 by the NASA Project Designation Committee); this uncrewed test validated, among other things, the radiation shielding of the crew cabin and was considered very successful, according to the *Saturn V Launch Vehicle Flight Evaluation Report – AS-501 Apollo 4 Mission*. It was an *"all-up"* flight: a bold gamble to test all the main components at once, rather than one at a time in separate flights.



Figure 7.15-2. Apollo 6: separation of the ring between the first and second stages, filmed by an onboard automatic camera.

The next flight, Apollo 5, was likewise uncrewed because it was an automatic test of the Lunar Module in Earth orbit, using a Saturn IB booster. Both of the LM's engines were fired and stage separation was performed. The flight also tested the automatic flight management systems (*Instrument Unit*) in the configuration that would later be used by the Saturn V.

Apollo 6 (Figure 7.15-2) was the second uncrewed *"all-up"* test flight of the Saturn V, also checking the capability of the command module to shield the crew from radiation during their brief transit through the Van Allen belts.

Its first stage was affected by violent pogo oscillations caused by structural resonances; two of the five engines of

the second stage underwent a premature shutdown (one because of the oscillations and one due to incorrect wiring); and the third stage yielded less thrust than expected.

These problems were analyzed and partially solved in later flights by changing the resonance frequencies of some components, adding dampers and scheduling additional wiring checks. That’s what test flights are for. Despite all this, some problems persisted and affected all Apollo flights.

In other words, the claim that the Moon landing missions suddenly became flawless is a myth.

7.16 Why is there no engine noise in the Moon landing audio?

IN A NUTSHELL: *Because the astronauts' microphones were very close to their mouths, so as to cut out background noise, and were designed to pick up only sounds at close range, just like aircraft pilot microphones or mobile phone microphones. Anyway, in a vacuum the rocket exhaust doesn't interact with an atmosphere, which is what produces most of the familiar roaring noise.*

THE DETAILS: Bill Kaysing, in Fox TV's *Conspiracy Theory: Did We Land on the Moon?*, says that *"the noise level of a rocket engine is up into the 140/150-decibel range. In other words, enormously loud. How would it be possible to hear astronauts' voices against the background of a running rocket engine?"* Indeed, the recordings of the astronauts' communications during landing and liftoff, while the rocket engines are running, contain no engine noise.

In the Lunar Module, the astronauts stood extremely close to the descent engine and the ascent engine is literally inside the cabin; yet there is no sign of engine noise in their radio communications.

This apparently unusual fact is actually quite normal and occurs not only in the Apollo recordings, but also in Shuttle or Soyuz liftoff recordings. Moreover, when we take a plane and the captain makes a passenger announcement, his voice isn't drowned out by the noise of the engines, even though the same noise is audible in the cabin.

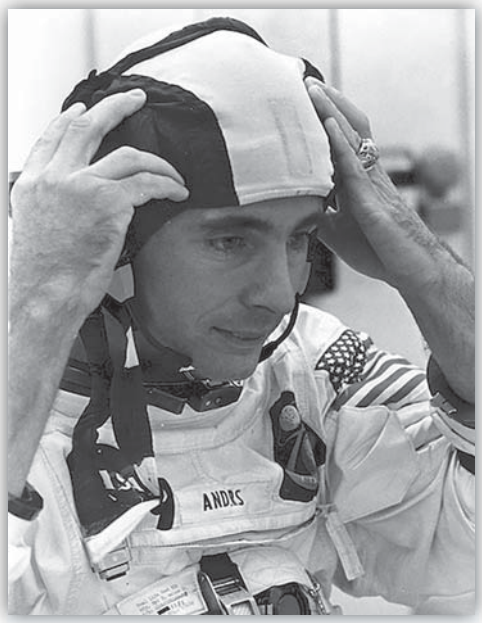


Figure 7.16-1. Bill Anders prepares for the Apollo 8 mission. Note the microphones on either side of his chin. NASA photo 68-H-1330.

The explanation is quite simple: the closeness of the microphones to the mouth allows the voice to cover any background engine noise. The microphones used for space flights, in aviation and in mobile phones are designed to cut out background noise in noisy environments by picking up only sound sources that are very close. Bill Anders (Apollo 8, Figure 7.16-1) reportedly called them *"tonsil mikes"* because he said that he had to shove them down his throat to make them work. This allowed the voice to drown out the roar of the engines – if there was any to begin with. Kaysing's claim is in fact incorrect: the noise of a spacecraft engine is not always *"enormously loud"*.

When a rocket engine operates in vacuum, its exhaust expands without encountering any obstacle: it doesn't collide at supersonic speed with an atmosphere and therefore it doesn't generate the shockwaves that instead cause the loud noise that is heard on the ground when a large rocket is launched.

Both Apollo astronauts and current spacecraft crews report that when they are in space, sometimes they hear a bang at the moment of ignition, before combustion stabilizes, and they feel occasionally intense vibration; but apart from this, they say that the engines are noiseless. It seems unlikely that they’re all lying.

7.17 How could a Lunar Module made of tinfoil withstand temperature extremes so well?

IN A NUTSHELL: *That "tinfoil" was just its thermal blanket: there was titanium underneath. The LM could stand on the Moon with one side exposed to the sun and the opposite side in shadow without overheating or freezing because it was insulated by that highly efficient multilayer thermal blanket. This might make it seem fragile, but it was actually better protected against temperature variations than the rest of the Apollo spacecraft.*

THE DETAILS: During the voyage to and from the Moon, the great thermal differences between the side of the spacecraft that was in full sunlight and the side in shadow required the astronauts to slowly roll the Apollo vehicle about its longitudinal axis to prevent it from overheating on one side and freezing on the other. This was known formally as *Passive Thermal Control* and less formally as *barbecue mode*.

The fuel tanks of the sixteen thrusters of the Service Module were in fact located close to the outer skin of the spacecraft and had to remain within very strict temperature and pressure ranges. The Command Module also has a heat shield which, if left to cool in shadow in space for more than thirteen hours, would have cracked and flaked with fatal consequences for the crew upon atmospheric reentry. The slow roll was devised as a solution to regulate the temperatures of these essential components of the Apollo vehicle.

The spacecraft, in other words, was extremely temperature-sensitive. Yet the Lunar Module, when it landed on the Moon, could no longer roll. It kept the same side exposed to the incessant heat of the sun and the opposite side exposed to the cold darkness of shadow for up to three days, without overheating or freezing.

This apparent technical contradiction actually has a very sensible explanation. Differently from the Command and Service Modules, the LM didn't have to cope with the aerodynamic stresses of the liftoff from Earth (during which it was protected by a streamlined fairing), didn't have a delicate heat shield to protect, and had no fuel tanks in direct contact with the outside skin. Accordingly, it could be equipped with a more effective thermal control system, which included a thermal blanket made of multiple layers of Mylar and/or Kapton. Spacers formed an insulating gap between the blanket and the pressurized crew compartment. The LM also had a sublimator similar to the one used for the spacesuits.



Figure 7.17-1. A prototype of the Lunar Module, preserved at the Smithsonian National Air and Space Museum, reveals the metallic structure under the thermal protection covering. Credit: NASM.

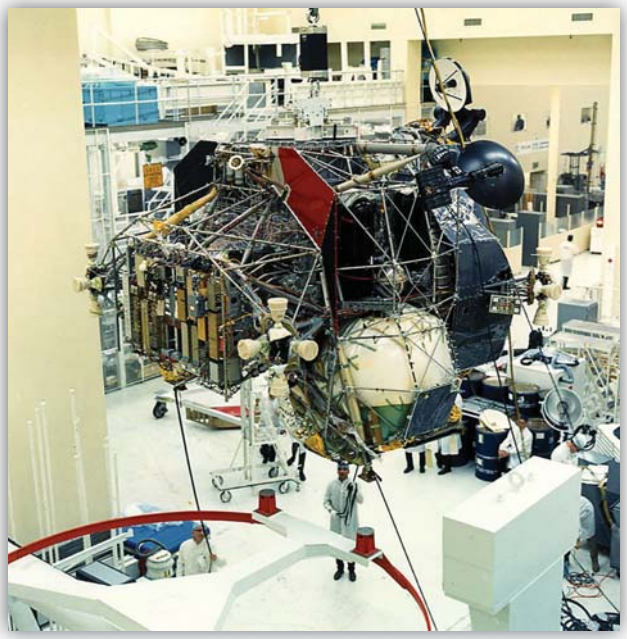


Figure 7.17-2. A Lunar Module under construction, seen from the rear, before being covered by its thermal blanket.

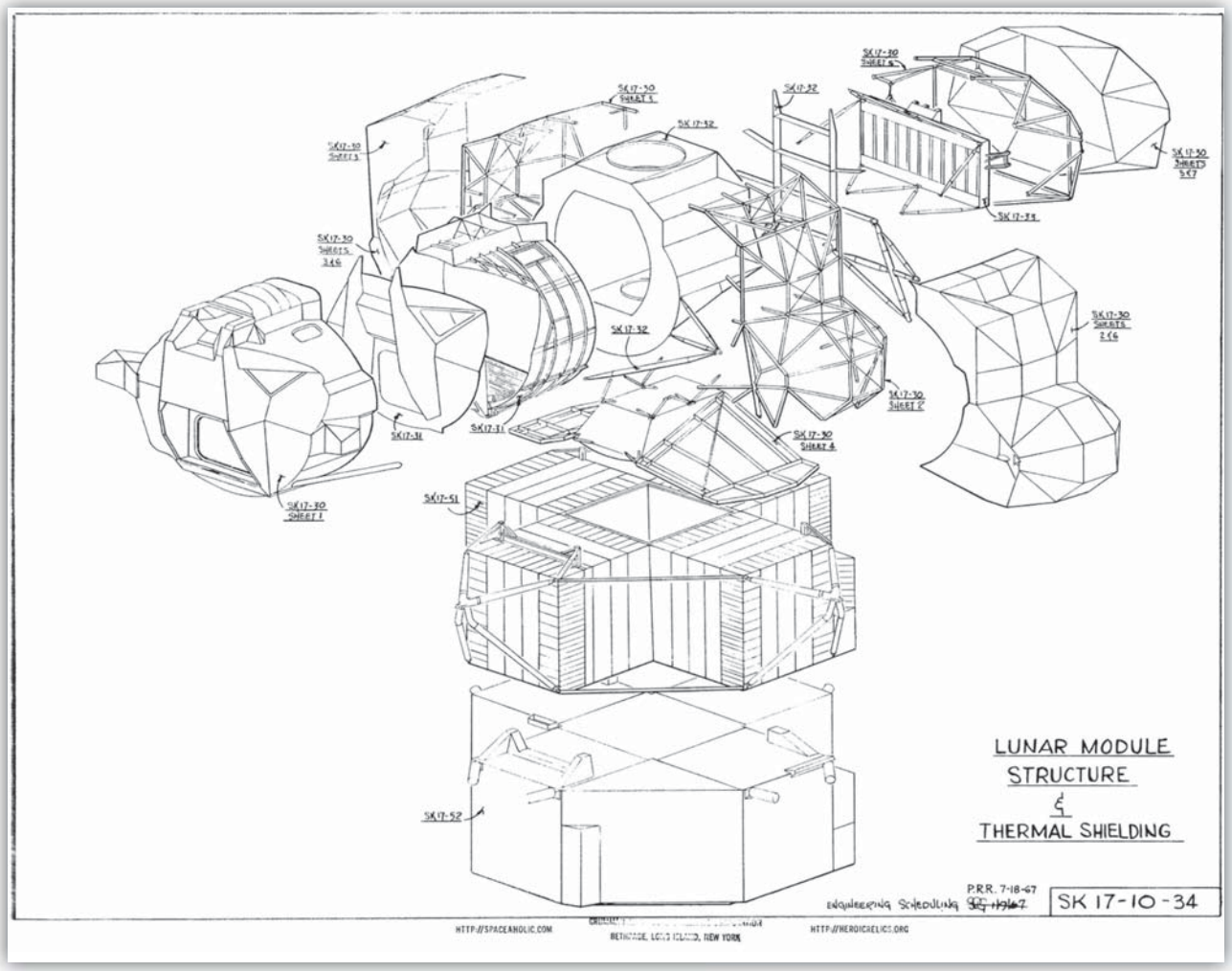


Figure 7.17-3. One of the many technical drawings that describe in detail the structure of the Lunar Module. Credit: HeroicRelics.com.

The apparently fragile, tin foil-like appearance of the LM was produced by this thermal blanket, which concealed the normal underlying metal structure shown in Figures 7.17-1 and 7.17-2 and in the illustrations of Figures 7.17-3 and 7.17-4.

Moreover, the thermal blanket is not exclusive to the Apollo LM: it was used for decades by the United States' Space Shuttles to protect the contents of its huge payload bay and is still used as an external shield by Russian Soyuz spacecraft, which spend up to six months in space, exposed unevenly to the heat of the Sun and to the chill of shadow in vacuum when they are docked to the International Space Station (Figure 7.17-5).

China, too, covers its uncrewed Moon landers with a thermal blanket which is even more similar to the one installed on the Apollo Lunar Module (Figure 7.17-6).

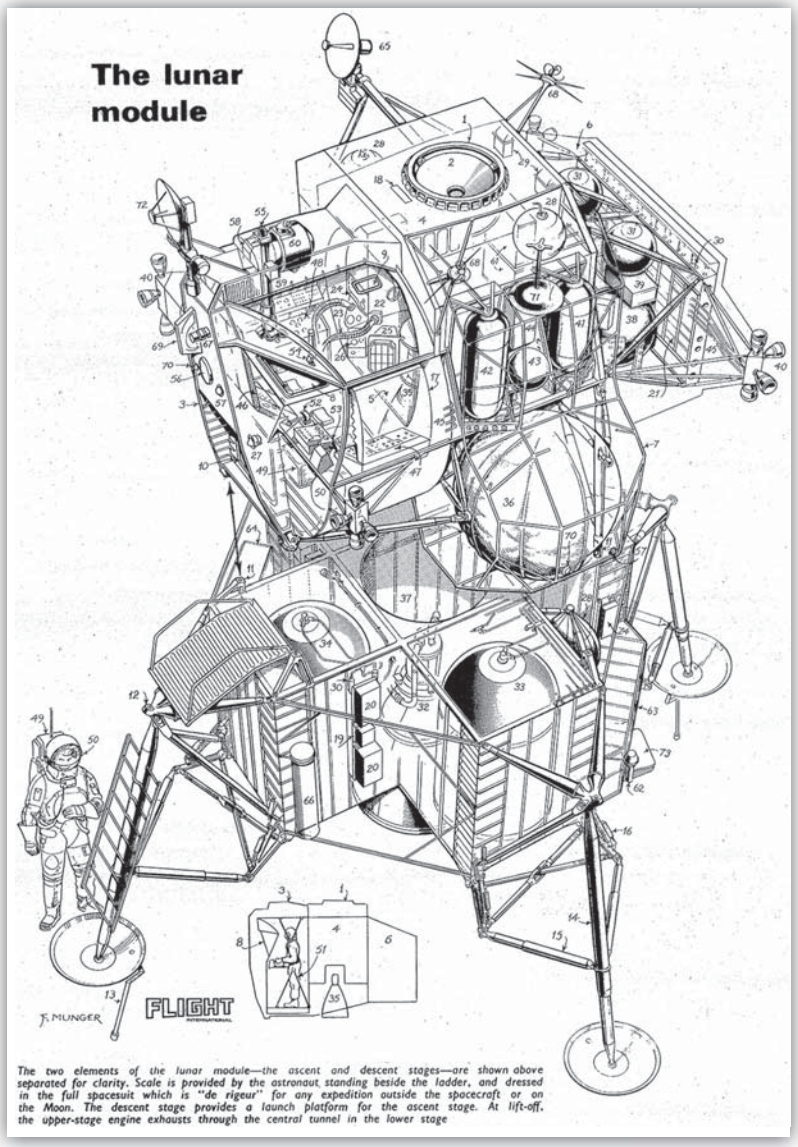


Figure 7.17-4. A highly detailed cutout of the Lunar Module, published by Flight International*, 6 February 1969. Scan excerpted from* De la Terre à la Lune*.*



Figure 7.17-5. A Russian Soyuz spacecraft (TMA-7) photographed in space shortly after undocking from the International Space Station, showing the thermal blanket that covers it. NASA photo ISS012-E-24219, 8 April 2006.

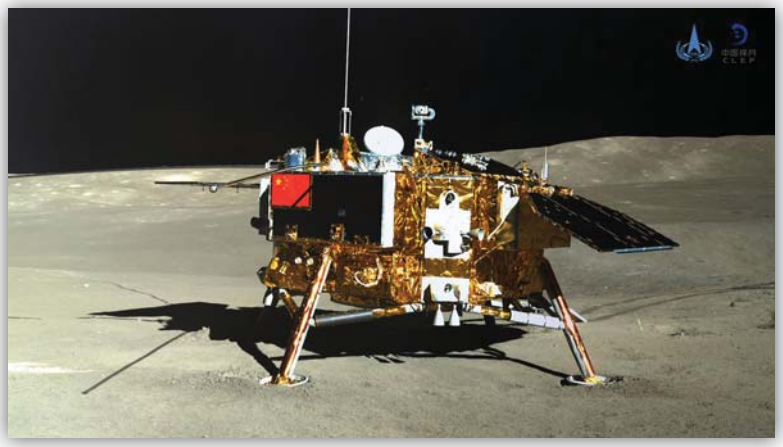


Figure 7.17-6. The Chinese Chang'e-4 Moon lander photographed on the far side of the Moon by its rover, Yutu 2, in January 2019.

7.18 Why don't the boot prints on the Moon match the spacesuit shoes?

IN A NUTSHELL: *Because the astronauts wore overshoes when they walked outside on the Moon.*



Figure 7.18-1. An example of the conspiracy theory. The suit photograph is sourced from the article Reboot the Suit! *by Phil Plait (Slate.com, 2015).*

THE DETAILS: Doubters and conspiracy theorists are disseminating online the claim that the boots on the spacesuits used by the Apollo astronauts, currently stored in museums, don't match the shape and sole pattern of the boot prints shown by NASA photographs (Figure 7.18-1).

Strictly speaking, this claim is actually correct: the *boots* of the Apollo spacesuits have a smooth sole and a heel, whereas the lunar boot prints have transverse ridges and no heel. But

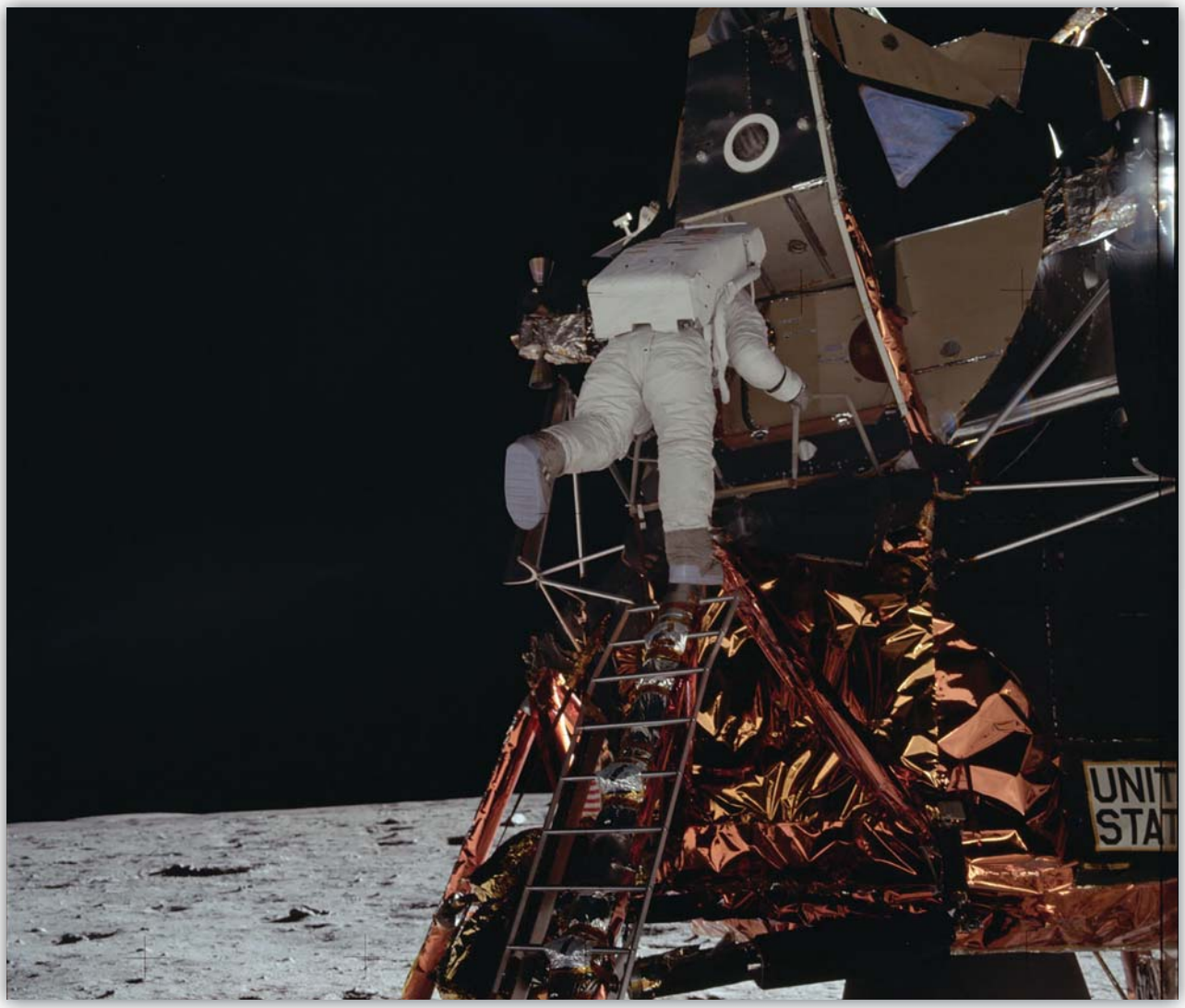


Figure 7.18-2. Buzz Aldrin is about to set foot on the Moon during Apollo 11. NASA photo AS11-40-5866.

the Apollo astronauts wore overshoes during their moonwalks, and those overshoes match the prints.



Figure 7.18-3. A detail of NASA photo AS11-40-5866, showing Aldrin's overshoes.

These protective overshoes were worn over the regular boots, which were integrated into the spacesuit in order to provide an airtight seal. The sole of the overshoes was made of silicone, the upper was made of woven stainless steel and other thermal protection materials. Their main purpose was to protect the astronauts from the temperature extremes of the ground (hot in sunlight, extremely cold in shadow) and from sharp rocks.

The structure and engineering of the Apollo overshoes are described, explained and illustrated in exquisite detail in the book *Moon Boot - The Story of the Apollo Lunar Overshoe* by David H. Mather, which is available for reading online.

Figures 7.18-4 and 7.18-5 show one of Gene Cernan's overshoes, returned to Earth after walking on the Moon in the final lunar mission, Apollo 17.



Figure 7.18-4. An overshoe worn on the Moon by Gene Cernan during Apollo 17, now currently owned by the National Air and Space Museum.



Figure 7.18-5. A bottom view of Cernan's overshoe. More photos are available at the website of the National Air and Space Museum.

8 Alleged physical anomalies

In addition to alleged anomalies in the visual record and in the technology of the Moon landings, there are also alleged anomalies of a physical nature. Conspiracy theorists argue that these anomalies show that the Apollo flights actually violated fundamental laws of physics.

For example, these theorists claim that the astronauts would have died crossing the Van Allen belts that encircle the Earth, that the photographic films and the astronauts themselves would have been unable to cope with the temperatures and radiation of space and of the lunar environment, that their pressurized suits would have inflated like balloons in a vacuum, and so forth.

These claims are based on misperceptions regarding the nature of space which are so widespread that issues such as radiation and the Van Allen belts have become popular questions even among non-doubters.

Answering these objections, which sometimes at least initially appear to make sense to anyone who is not thoroughly familiar with the actual physics of space travel, requires substantial research and access to rather uncommon scientific expertise. The same applies to understanding the answers.

Accordingly, this chapter is more complex than the previous ones, although every effort has been made to clarify the physics involved in each instance.

Explaining the fallacies of these claims is an excellent opportunity to talk about the real nature of space, dispel these common myths and explain radio communications in space, the behavior of dust in a vacuum, the inner workings of the Apollo spacesuits, and other physical aspects of spaceflight.

8.1 How come the Van Allen radiation belts didn't kill the astronauts?

IN A NUTSHELL: *Because these belts are not as deadly as they're often made out to be and also because they're* belts*, so you can fly* around *them. Russian spaceflights flew animals through them without problems. NASA also conducted sensor-laden uncrewed test flights to measure the effectiveness of the shielding of the Apollo command module. The trajectories of all the moonshots were*

calculated to fly around the core of these donut-shaped belts and pass rapidly through their less intense outer portions. The astronauts on the International Space Station periodically pass through parts of these belts and they don't die.

THE DETAILS: Many Moon hoax proponents claim that any crewed lunar mission would be impossible due to the allegedly lethal barrier of the *Van Allen belts*, two regions of radiation that wrap around the Earth at distances that can vary according to solar activity but are roughly located between 100 and 10,000 kilometers (62 to 6,200 miles) for the more intense inner belt and between 18,000 and 60,000 kilometers (11,100 to 37,000 miles) for the weaker outer belt (Figure 8.1-1).

Vintage technical literature on the subject (for example the papers listed in the *References* chapter of this book) shows that the potential danger posed by the Van Allen belts was well-known when the lunar missions flew, since the belts had been discovered in 1958 by United States physicist James Van Allen (1914-2006). The issue was considered perfectly manageable with a few precautions, as described in the January 1969 report *Radiation Plan for the Apollo Lunar Mission*.

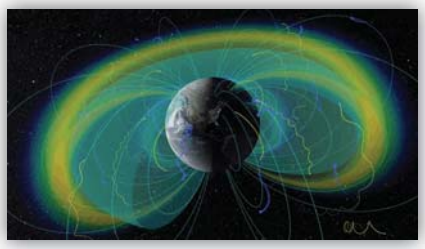


Figure 8.1-1. An illustration of the Van Allen belts, with the confined charged particles (in blue and yellow) and the boundary of the plasmapause (blue-green surface). Credit: NASA Scientific Visualization Studio.

The estimates made by the experts proved to be correct: in 1968, the Soviet space probe Zond 5 flew through the Van Allen belts to carry around the Moon several living creatures, which returned unharmed from their voyage.

For the Apollo missions, exposure during the crossing of the Van Allen belts was calculated and measured by means of uncrewed test flights: specifically, Apollo 6 (April 1968) carried into Earth orbit an Apollo capsule equipped with instruments for measuring the capability of the spacecraft to block the radiation from the belts. It was found that the exposure was comparable to the effects of a few medical X-rays and therefore was quite tolerable for short periods.

The very first human beings to fly beyond the Van Allen belts were the astronauts of Apollo 8. According to NASA's *Biomedical Results of Apollo* report (1975), over the course of the entire flight Lovell, Borman and Anders accumulated a radiation dose of 1.6 millisieverts. This is the equivalent of about twenty chest X-rays and is therefore far from being immediately lethal as some conspiracy theorists argue.

In other words, the actual level of risk entailed by the Van Allen belts was well-known and tested *long before the Moon landings*.

Moreover, the Apollo 11 *Mission Report* notes that the total radiation dose measured by the dosimeters worn by the astronauts during the trip was between 2.5 and 2.8 millisieverts. The Van Allen-specific dosimeter detected doses of 1.1 millisieverts for the skin and 0.8 millisieverts for the depth reading, well below medically significant values.

For comparison, according to the US National Council on Radiation Protection and Measurement the annual average radiation dose per person in the United States is 6.2 millisieverts; 52% of this is of natural origin.

We don't have to take NASA's word about the Van Allen belts. There is clear consensus in the science community on the matter, as shown for example by the article *The Van Allen Belts and Travel to the Moon* by Bill Wheaton (2000), specialist in gamma ray astronomy at the Jet Propulsion Laboratory (JPL).

Wheaton provides objective data regarding radiation in space and specifically in the Van Allen belts. It turns out that the data published by NASA on this subject must be true, otherwise today's automatic satellites would be fried, since they fly through the belts and their equipment, if not shielded adequately against radiation, will malfunction.

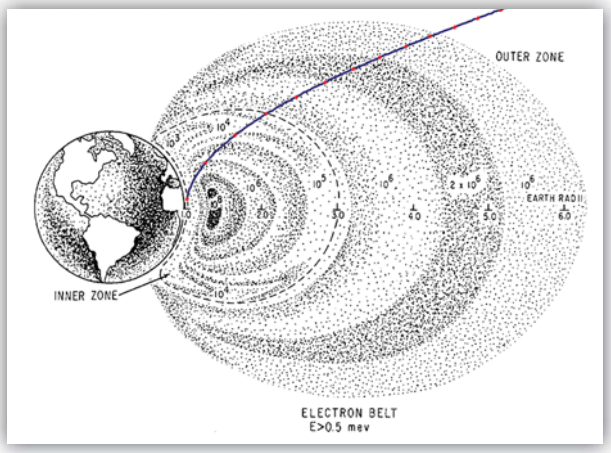


Figure 8.1-2. The outbound trajectory of Apollo 11. The return path was even more inclined. Source: Rocket & Space Technology.

James Van Allen, from whom the belts get their name, had already stressed, as early as 1960 in the article *On the Radiation Hazards of Space Flight,* that these belts don't encase the entire planet from pole to pole, but form a sort of donut that fades in intensity from approximately 30° above and below the Earth's equator. Therefore, to fly around them or pass through their weaker regions it is sufficient to use an adequately inclined trajectory, which is what all the Apollo spacecraft did, both on the way to the Moon and on the way home (Figure 8.1-2).

Records show that Apollo 11's transit through the Van Allen belts lasted a total of 90 minutes, flying around the region of maximum intensity in about ten minutes.

The South Atlantic Anomaly

Many conspiracy theorists and doubters who claim that the Van Allen belts are an impassable barrier are unaware of a fact that undermines their argument completely: the astronauts of the International Space Station periodically

fly through a protrusion of these belts known as the *South Atlantic Anomaly*.

The Van Allen belts aren't as clear-cut and uniformly arranged as often shown in schematic illustrations. Over the South Atlantic they reach far closer to Earth than their average distance from the planet (Figures 8.1-3 and 8.1-4). They actually encroach the orbit of the Space Station, approximately 400 kilometers (250 miles) from the Earth's surface, and reach down to an altitude of just 200 kilometers (125 miles).

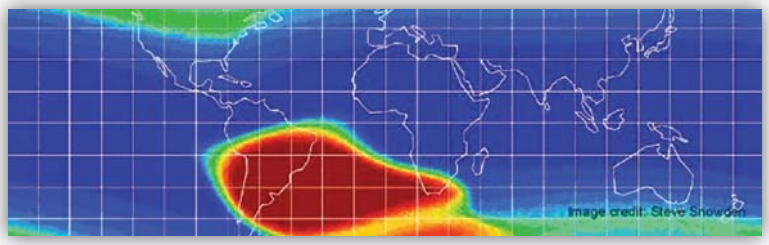


Figure 8.1-3. The South Atlantic Anomaly as mapped by the ROSAT satellite (NASA, 2008).

Accordingly, the Station passes through this region of the Van Allen belts every time it flies over the South Atlantic, as it does periodically in its highly inclined orbit (51.6°) with respect to the Earth's equator. If the belts were as lethal as conspiracy theorists claim, the occupants of the Space Station would die on board, since they cross this region many times during their six-month or year-long missions, whereas the Apollo astronauts crossed the outer regions of the belts only twice per mission.



Figure 8.1-4. The South Atlantic Anomaly in an animation of the European Space Agency [http://tiny.cc/eo20dz].

The shielding of the Space Station greatly reduces the exposure of the astronauts to the high-energy particles of the Van Allen belts, but it doesn't protect the external TV cameras of the Station, which often broadcast live on the Internet. This produces a weird phenomenon: since electronic components can be affected by the charged particles of the belts, their effects on the sensors of these TV cameras can be watched live, as shown in the videos of Figures 8.1-5 and 8.1-6, which give the impression of snow falling at night.

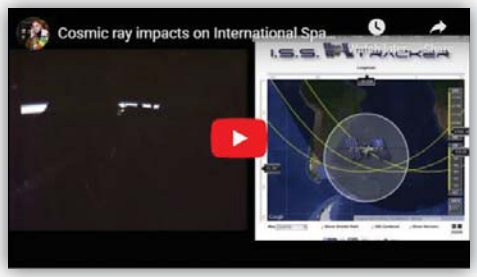


Figure 8.1-5. On the left, the image broadcast by the external TV cameras of the Space Station on December 30, 2014, at 1:40 CET; on the right, the location of the Station during the broadcast. The dots and streaks are the effect of charged particles on the camera sensors [http://tiny.cc/gr20dz].



Figure 8.1-6. The Station flies through the South Atlantic Anomaly on 8 January 2018 at 1:29 CET [http://tiny.cc/bt20dz].

The sensitivity of electronic components to charged particles is an aspect of the Van Allen

belts that is often ignored by nonexperts and is a technical problem that needs to be handled by any satellite that flies through the belts frequently. These particles, for example, can alter the values stored in a computer memory, causing malfunctions and restarts, or can damage permanently the sensors of a still camera or TV camera, as reported by astronaut Don Pettit:

> *Free from the protection offered by the atmosphere, cosmic rays bombard us within Space Station, penetrating the hull almost as if it was not there. They zap everything inside, causing such mischief as locking up our laptop computers and knocking pixels out of whack in our cameras. The computers recover with a reboot; the cameras suffer permanent damage. After about a year, the images they produce look like they are covered with electronic snow.*

James Van Allen himself replies

In February 2003, a member of the Cosmoquest forum reported that he had written to James Van Allen asking for information on the effects that belt radiation might have had on astronauts and that he had received the following answer:

> *Dear Mr. Lambert,*
>
> *In reply to your e-mail, I send you the following copy of a response that I wrote to another inquiry about 2 months ago --*
>
> *- The radiation belts of the Earth do, indeed, pose important constraints on the safety of human space flight.*
>
> *- The very energetic (tens to hundreds of MeV) protons in the inner radiation belt are the most dangerous and most difficult to shield against. Specifically, prolonged flights (i.e., ones of many months' duration) of humans or other animals in orbits about the Earth must be conducted at altitudes less than about 250 miles in order to avoid significant radiation exposure.*
>
> *- A person in the cabin of a space shuttle in a circular equatorial orbit in the most intense region of the inner radiation belt, at an altitude of about 1000 miles, would be subjected to a fatal dosage of radiation in about one week.*

- However, the outbound and inbound trajectories of the Apollo spacecraft cut through the outer portions of the inner belt and because of their high speed spent only about 15 minutes in traversing the region and less than 2 hours in traversing the much less penetrating radiation in the outer radiation belt. The resulting radiation exposure for the round trip was less than 1% of a fatal dosage - a very minor risk among the far greater other risks of such flights. I made such estimates in the early 1960s and so informed NASA engineers who were planning the Apollo flights. These estimates are still reliable.

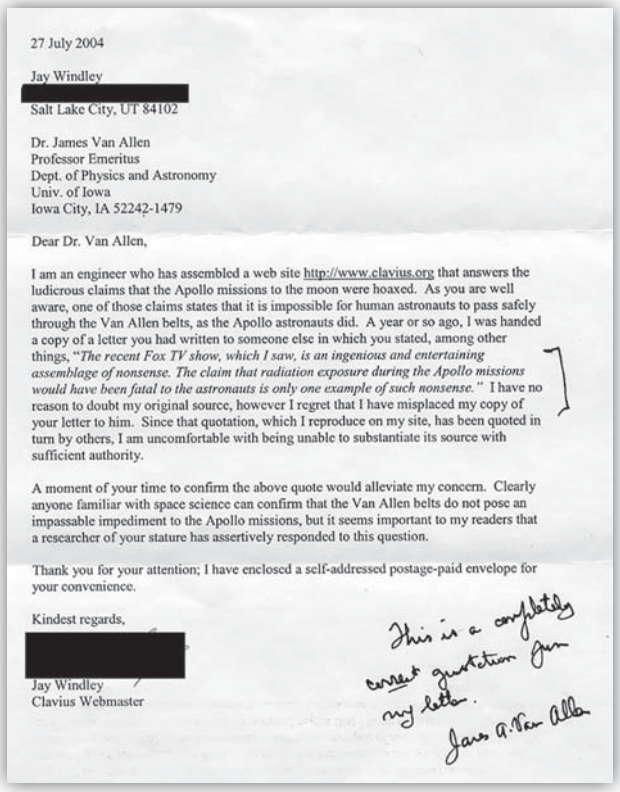
- The recent Fox TV show, which I saw, is an ingenious and entertaining assemblage of nonsense. The claim that radiation exposure during the Apollo missions would have been fatal to the astronauts is only one example of such nonsense.

James A. Van Allen

In 2004, Jay Windley of Clavius.org wrote to professor Van Allen, asking him to authenticate this reply and received handwritten confirmation from the scientist (Figure 8.1-7): *"This is a completely correct quotation from my letter"*.

Further reading

- *Van Allen radiation belt*, Britannica.com;
- *How did Apollo deal with the Van Allen Radiation belts?*, video by Curious Droid;
- *Apollo Rocketed Through the Van Allen Belts*, by Amy Shira Teitel, *Popular Science*, 19 September 2014;
- *Why Aren't the Van Allen Belts a Barrier to Spaceflight?*, Jillian Scudder, assistant professor of physics and astronomy, *Forbes.com*, 16 June 2017.



27 July 2004

Jay Windley
[redacted]
Salt Lake City, UT 84102

Dr. James Van Allen
Professor Emeritus
Dept. of Physics and Astronomy
Univ. of Iowa
Iowa City, IA 52242-1479

Dear Dr. Van Allen,

I am an engineer who has assembled a web site http://www.clavius.org that answers the ludicrous claims that the Apollo missions to the moon were hoaxed. As you are well aware, one of those claims states that it is impossible for human astronauts to pass safely through the Van Allen belts, as the Apollo astronauts did. A year or so ago, I was handed a copy of a letter you had written to someone else in which you stated, among other things, *"The recent Fox TV show, which I saw, is an ingenious and entertaining assemblage of nonsense. The claim that radiation exposure during the Apollo missions would have been fatal to the astronauts is only one example of such nonsense."* I have no reason to doubt my original source, however I regret that I have misplaced my copy of your letter to him. Since that quotation, which I reproduce on my site, has been quoted in turn by others, I am uncomfortable with being unable to substantiate its source with sufficient authority.

A moment of your time to confirm the above quote would alleviate my concern. Clearly anyone familiar with space science can confirm that the Van Allen belts do not pose an impassable impediment to the Apollo missions, but it seems important to my readers that a researcher of your stature has assertively responded to this question.

Thank you for your attention; I have enclosed a self-addressed postage-paid envelope for your convenience.

Kindest regards,

[redacted]

Jay Windley
Clavius Webmaster

This is a completely correct quotation from my letter.
James A. Van Allen

Figure 8.1-7. Jay Windley's letter with James Van Allen's handwritten reply.

8.2 If the Van Allen belts weren't a problem for Apollo, why does NASA need to test the new Orion spacecraft?

IN A NUTSHELL: *Because it's a new and different vehicle and new vehicles are always tested before putting people in them.*

THE DETAILS: In a video (Figure 8.2-1), NASA engineer Kelly Smith discusses the new Orion spacecraft and its test flights, which will pass through the Van Allen belts. According to conspiracy theorists, his words *"We must solve these challenges before we send people through this region of space"* (at 1:35) mean that NASA has never sent human beings through the Van Allen belts and that this challenge still has to be met. Therefore, they argue, the Moon landings must be fake.



Figure 8.2-1. The video in which Kelly Smith talks about the challenges of Orion [http://tiny.cc/kv20dz].

First of all, we might ask ourselves why would a NASA engineer, in a NASA video, make such an astonishing disclosure, and why he would do so in such a casual manner. Actually, there's no disclosure at all; there's only an arbitrary and twisted interpretation of his words.

Here's a full transcript, which helps to understand the context:

> *My name is Kelly Smith and I work on navigation and guidance for Orion. Before we can send astronauts into space on Orion, we have to test all of its systems, and there's only one way to know if we got it right: fly it in space. For Orion's first flight, no astronauts will be aboard. The spacecraft is loaded with sensors to record and measure all aspects of the flight in every detail. We are headed 3600 miles above Earth, 15 times higher from the planet than the International Space Station. As we get further away from Earth, we'll pass through the Van Allen belts, an area of dangerous radiation.* ***Radiation like this can harm the guidance systems, onboard computers or other electronics on Orion.*** *Naturally, we have to pass through this danger zone twice: once up, and once back. But Orion has protection. Shielding will be put to the test as the vehicle cuts through the waves of radiation. Sensors aboard will record radiation levels, for scientists to study. We must solve these challenges before we send people through this region of space.*

First of all, notice that Smith is discussing damage to the *components* of the spacecraft, not to the astronauts. He specifically mentions harm to *"the guidance systems, onboard computers or other electronics"*.

He says this because the integrated electronics used in today's spacecraft are more sensitive to radiation that the simple wiring and early integrated circuits of the 1960s, as mentioned in Section 8.1.

This may seem strange to anyone who is not familiar with electronics, but today's components are more vulnerable than old ones because they are far smaller, and therefore a single high-energy particle that hits one of their microscopic memory cells can alter its contents and therefore generate incorrect information or instructions. The relatively small number of memory cells of the Apollo computers, being much larger, could not be affected so easily.

The greater radiation resistance of vintage components is well-documented by uncrewed spaceflights: the processors, memories and other components installed in space probes, for example, are often far more "primitive" than the ones we commonly use in our computers or smartphones on Earth, indeed because they must be able to withstand a hostile environment: not just radiation, but also temperature extremes.

Secondly, Smith is talking specifically about the Orion spacecraft. Therefore, when he says *"before we send people through this region of space"* he is implying *"on Orion"*. He's a NASA engineer: he knows very well that the Apollo flights crossed the margins of the Van Allen belts, so there's no need for him to specify this pedantically.

The fact that the Orion spacecraft needs to be tested should be no big surprise. It's a new vehicle, and like every new vehicle it has to be tested before risking human lives in it. Just because Ford carried out crash tests on its previous cars, it doesn't mean that new models can be marketed without going through similar tests. Sure, computer simulations and calculations have been performed, but since the lives of astronauts are at stake, estimates are not enough. The flight test mentioned by Smith was performed in December 2014 (EFT-1).

The following NASA video (Figure 8.2-2) describes another uncrewed Orion test flight around the Moon, known as EM-1 (*Exploration Mission 1*), and also clarifies the differences in trajectory with respect to the Apollo missions that require these



Figure 8.2-2. A NASA video describing test flight EM-1 [http://tiny.cc/bx20dz].

experimental missions. The transit through the Van Allen Belts is shown from 4:34 onward.

According to public statements by Nujoud Merancy, in charge of planning the Orion exploration missions for NASA, in response to a question from me, Orion will not actively avoid the densest regions of the Van Allen belts, as the Apollo spacecraft did, although the trajectory will not be as centered on the most intense regions of the belts as shown in the video.

Merancy added that thanks to advanced radiation protection and to the use of four computers working in parallel, there is not much risk to the vehicle; for crews, instead, calculations indicate that their exposure for the whole mission will be lower than that experienced over six months in the International Space Station; moreover, if any trajectory were to risk overexposing the crew, it would be tailored before flight to avoid dense radiation patches by increasing the off-plane component of the trajectory.

8.3 How come astronaut Terry Virts said that we can't go to the Moon?

IN A NUTSHELL: *Because we can't go* right now*, not because we've never been. He clearly says so.*

THE DETAILS: A statement made by US astronaut Terry Virts during a televised interview from the International Space Station in March 2015 (Figure 8.3-1) has been interpreted by some conspiracy theorists as an admission that no human spaceflight has ever reached the Moon.



Figure 8.3-1. Terry Virts (right) as he makes the allegedly controversial statement. Italian astronaut Samantha Cristoforetti is on the left.
Source: YouTube/NASA [http://tiny.cc/ilhgnz].

The unseen and unidentified interviewer asks, *"And what comes after the International Space Station, once its mission is over? How do we ensure the presence of humans in space?"*

Virts replies verbatim as follows:

> *Well, that's a great question. The plan that NASA has is to build a rocket called SLS, which is a heavy lift rocket. It's something that is much bigger than what we have today, and it will be able to launch the Orion capsule with humans on board as well as landers or other components to destinations beyond Earth orbit.* ***Right now we only can fly in Earth orbit, that's the farthest that we can go****, and this new system that we're building is gonna allow us to go beyond and hopefully take humans into the Solar System to explore. So the Moon, Mars, asteroids... there's a lot of destinations that we could go to and we're building these building-block components in order to allow us to do that eventually.*

Some conspiracy theorists claim that the astronaut's words *"we only can fly in Earth orbit, that's the farthest that we can go"* mean that we *never* went beyond Earth orbit. But Virts begins by specifying very clearly *"right now"*. He is not saying that we've *never* had crewed spacecraft capable of flying beyond low earth orbit: quite the contrary. He says *"right now"* to contrast the current situation with the past.

In April 2018 I emailed Terry Virts, asking if he'd like to personally clarify his words, and he kindly replied by email with the following answer, which I include with his permission:

> *Of course what I was saying was that in 2015/16/17/18 we are not able to send humans beyond low earth orbit. Hopefully in the near term, probably with commercial rockets such as SpaceX's Falcon Heavy or even BFR, and perhaps with SLS/Orion, we will be able to do once again what we did in 1968-1972, i.e., send humans to the Moon. And I really hope that eventually we can send them beyond the moon, to Mars. Of course we did this in the 1960s and 1970s, but have not done it since, for a myriad of political reasons. I hope that this drought will come to an end soon.*

In other words, this video doesn't provide any proof of conspiracy, but it does prove how conspiracy theorists are willing to cherry-pick and distort other people's words in order to adapt them to their preconceptions.



Figure 8.3-2. The full interview with Samantha Cristoforetti and Terry Virts [http://tiny.cc/o320dz].

For context, the full interview with Virts and Cristoforetti is available in Figure 8.3-2. It is dated 13 March 2015 and the interviewers on the ground are WTOP Radio in Washington, DC, and Euronews.

8.4 How come deep space radiation didn't kill the astronauts?

IN A NUTSHELL: *Because it's not as deadly as some people claim. The radiation normally present in space at lunar distances from Earth is comparable to the radiation affecting the astronauts on the International Space Station, who stay in space up to one year at a time and don't come back dead. A round trip to the Moon lasted no more than twelve days.*

THE DETAILS: It is often claimed that the lethal radiation of deep space would have killed any Apollo astronauts who tried to get to the Moon, venturing outside of the safety of Earth's protective magnetic field, which provides a shield against this radiation.

However, the claim's premise is factually incorrect: on Earth we're protected against deep space radiation mainly by the atmosphere, not by the planet's magnetic field, which has a small role in shielding us.

The dose of cosmic radiation (ions traveling at nearly the speed of light) that reaches anyone who lives at sea level is approximately 0.3 millisieverts/year, which is the equivalent of a couple of chest X-rays. This rises to 0.8-1.2 millisieverts/year for people living at high altitudes, for example on a 3,000-meter (10,000-ft) mountain range. At 12,000 meters (40,000 feet), the usual altitude of airline flights, cosmic radiation rises further to 28 millisieverts/year: nearly a hundred times more than at sea level, even though the aircraft's occupants are still well within the Earth's magnetic field.

Once you leave the atmosphere, this radiation increases considerably right away. In low earth orbit, such as on the International Space Station, it averages 100 millisieverts/year. At this altitude, the protective effect of the Earth's magnetic field becomes significant, but only for astronauts who follow equatorial orbits; the ISS has a highly inclined orbit.

In interplanetary space the dose is 130-250 millisieverts/year and by some estimates may be as high as 800 millisieverts/year on a trip to Mars; on the surface of the Moon it drops to 70-120 millisieverts/year.[1]

In other words, the doses of deep space radiation to which the Apollo vehicles and the astronauts were exposed during missions to the Moon are comparable with those that affect the International Space Station, yet the occupants of the ISS stay in space for up to *one year* without dying of radiation exposure, compared to a maximum of twelve days for the lunar astronauts during Apollo 17.

1 *Shielding Space Travelers*, Eugene N. Parker, emeritus physics professor at the University of Chicago and member of the National Academy of Sciences, in *Scientific American*, March 2006.

8.5 Shouldn't X-ray radiation in space have fogged the films?

IN A NUTSHELL: *No. The X-ray doses received in space by films during a Moon trip would not have been strong enough. The tests performed by conspiracy theorists use flawed methods and vastly exaggerated doses compared with those to which films might be exposed during a journey to the Moon and back.*

THE DETAILS: In the book *Dark Moon,* Mary Bennett and David Percy describe tests conducted by physicist David Groves: films exposed to X-rays became fogged or their pictures were deleted. Therefore, they claim, the same should have happened to the films taken to the Moon.

However, these tests exposed the film to X-rays *directly*, without any protection, whereas the Apollo films were kept for almost all of the journey inside shielded canisters, which in turn were protected by the shielding provided by the Apollo spacecraft in the Command Module and in the Lunar Module. Even during the moonwalks, the films were shielded by the metal of their Hasselblad magazine.

Groves' tests also bombarded the test films with an 8-MeV (million electron volts) beam, using a linear accelerator, while astronomers report that X-rays from space have an energy level of less than 5 keV (thousand electron volts), i.e., approximately 1,600 times weaker than the radiation that fogged films in the Groves experiment.

In other words, the tests are crucially flawed: it's as if they compared drinking a single glass of water with drinking one thousand six hundred glasses at once (about 320 liters or 84.5 US gallons).

This difference is crucial not only in terms of numbers, which show how unfair the tests presented by Bennett and Percy are, but also in terms of the shielding required: X-rays with an energy of less than 5 keV are stopped by a few sheets of paper. Under 3 keV, just a few dozen centimeters (inches) of air are all that it takes.[2]

2 *Welcome to the World of X-ray Astronomy*, Nasa.gov.

Moreover, Groves reports that he exposed the test films to 25, 50 and 100 *rem* of radiation, but this unit is wholly inappropriate, because it refers to radiation absorbed by human tissue. Using it for films suggests an unprofessional approach to the matter: it's like saying that distances are measured in liters (or gallons).

However, for X-rays 1 rad is equivalent to 1 rem, so we could assume that Groves meant doses of 25 to 100 rad. Even so, as discussed in Section 8.4, 25 rad (the lowest figure claimed by Groves) are equivalent to *several years* in space.

8.6 Wouldn't the camera films have melted or frozen on the Moon?

IN A NUTSHELL: *No. Temperature extremes refer to the lunar* surface*, from which the films were insulated by vacuum. In any case they were not reached during the Apollo missions, which landed on the Moon shortly after the beginning of the two-week-long lunar day at the landing sites, when ground temperatures were far lower. The films were also a heat-resistant type used for high-altitude reconnaissance and the cameras were treated to reflect the heat from direct exposure to the Sun, which is comparable with the heat from sunlight on a mountaintop on Earth.*

THE DETAILS: Gerhard Wisnewski is one of the many hoax theorists who claim that the extreme temperatures of the lunar surface would have damaged the camera films irreparably and therefore the photographs must be fake. In his book *One Small Step*, Wisnewski argues thus:

> *There was no other protection against temperature extremes of over 100°C plus and under 100°C minus [...] It was to be expected that the sensitivity of the chemical films would be affected by the extreme temperatures – if indeed not rendered useless by temperatures of over 100°C*.

However, a little fact-checking shows that Wisnewski's premise is incorrect due to a common misconception about temperatures in space.

It's true that there are great temperature variations on the Moon. Data from recent lunar probes, such as the Lunar Reconnaissance Orbiter (2009) or Chang'e-4 (2019), show maximum temperatures of 110°C (230°F) and minimum temperatures of -180°C (-292 °F) at the lunar equator, and even -190°C on the far side; in some polar regions, which are perennially in shadow, the temperature plunges to -238°C (-397°F). But all these values refer to the temperature of the lunar *surface*.

This is a crucial detail, since on the Moon there's no significant atmosphere that can be heated by the ground and therefore there is no way to transfer heat from the ground to the films. Vacuum is a very good heat insulator, as thermos flasks demonstrate. In a vacuum there is no heat transfer by *conduction* or *convection*, which are the main heating and cooling processes on Earth. There's no air to warm or chill objects by contact.

On the Moon and in space, heat is transferred between objects that are not in mutual contact only by *radiation*: the same principle by which we are warmed when standing

next to a fire. Clearly the heating produced by radiation is nowhere as intense as heating by direct contact: there's a significant difference between warming your hands in front of a fire and putting your hands *in* the fire.

Consequently, on the Moon the temperature of the ground is essentially irrelevant as regards film temperatures and claiming that ground temperatures would overheat or freeze the films is a misleading and amateurish scientific error.

Wisnewski also doesn't consider that the reported ground temperature extremes are reached only far into the lunar day (which entails fourteen Earth days of uninterrupted exposure to the Sun) and just before local sunrise (after fourteen days of continuous darkness). But all the Moon landings took place shortly after local sunrise, when the temperatures were far from these extremes.

The maximum elevation of the Sun above the horizon during the Apollo moonwalks was 48.7°, at the end of the third excursion of the Apollo 16 crew. This mission recorded *ground* temperatures of 57°C (135°F) in sunlight and -100°C (-140°F) in shadow.

The only heat to which the Apollo films were exposed was therefore produced by solar radiation. An object exposed to the Sun on the Moon receives essentially the same amount of heat that it receives on Earth on a mountain top on a clear day, since heat transfer by radiation depends on the distance from the heat source and the Earth and the Moon are essentially at the same distance from the Sun. There's nothing magically incendiary about the sunlight that strikes the Moon: in terms of heat, it's roughly the same that we receive here on Earth.

In other words, a film exposed to sunlight on the Moon is affected by the same level of thermal stresses that wouldaffect it on Earth on a bright sunlit day on a high mountain. As we all know, before digital cameras were introduced, tourists were quite able to take photographs in the mountains and even in the heat of tropical forests or deserts without their films melting or spoiling their colors.

One might object that on the Moon the sunlit side of the camera is heated intensely while the shadow side cools just as dramatically. However, these processes are not instantaneous, because once again there's no air to carry the heat from the camera body to the film or away from the film into space. The camera is in vacuum and therefore the film is like in a thermos flask. Heat transfer between the film and the camera occurs only at their few points of mutual contact. In any case, the cameras used on the Moon were being moved all the time by the astronauts and therefore were never left for long with the same side exposed to the Sun.

Besides, if someone argues that it would have been impossible for film to withstand the vacuum and the temperatures on the Moon, then he or she is implying that *all* the photographs ever taken on film in space during Russian, European and American spacewalks are fake, because there are no differences, in terms of temperature, vacuum and exposure to sunlight, between the conditions on the Moon and those in Earth orbit.

For example, Figure 8.6-1 shows US astronaut Ed White during his spacewalk outside the Gemini 4 spacecraft in 1965. He is carrying an ordinary camera and his picture was taken with another camera, which also was outside in space. Neither of the films in these cameras melted or was spoiled.

Moreover, the Apollo lunar cameras had been treated specifically to have reflective surfaces instead of the



Figure 8.6-1. Ed White used an ordinary camera (which can be seen here in front of the astronaut's chest), with no thermal protection, during his spacewalk in 1965. NASA photograph S65-30431.



Figure 8.6-2. A Hasselblad 500 EL lunar camera.

traditional black finish, as shown in Figure 8.6-2. This treatment reflected most of the heat received from the Sun.

In addition, lunar photography didn't use ordinary film, but a special 70 mm Kodak film engineered specifically for high-altitude reconnaissance applications, in which it had to deal with air temperatures as low as -40°C (104°F). This film had a custom-made thin polyester base (Estar), with a melting point of 254°C (490°F), and used an Ektachrome emulsion capable of providing adequate results over a wide temperature range.

Sometimes it is objected that chemical films have a narrow temperature range, so much that professional photographers are very careful to keep their films warm or cool as needed. But this is an *optimum* range, which yields the best possible colors: it doesn't imply that the film will break or melt outside of this interval.

8.7 Wouldn't sunlight outside on the Moon have burned or boiled the astronauts' faces?

IN A NUTSHELL: *No. It doesn't affect the faces of astronauts who routinely perform spacewalks outside the International Space Station, where sunlight is essentially as strong as on the Moon. The clear part of the helmet shields their face against the ultraviolet light that causes sunburns.*

THE DETAILS: Some Moon hoax proponents argue that the fiercely strong sunlight on the Moon, unfiltered by the Earth's protective atmosphere, should have caused intense sunburns or overheating, yet we see photographs and footage of the moonwalkers walking around in full sunlight, sometimes even with their protective visor up (Figure 8.7-1), which would have been impossible or extremely hazardous, as claimed for example by Mary Bennett and David Percy in their book *Dark Moon*.[3]

3 *Dark Moon: Apollo and the Whistle-Blowers* (2001), page 102.

This claim is contradicted by the simple fact that even the astronauts who work outside the International Space Station are exposed to full sunlight without the shielding of the Earth's atmosphere, just like their former colleagues on the Moon, yet they don't get sunburned or overheated, even when they lift their reflective visors, as shown for example in Figures 8.7-4 to 8.7-8. The same applies to the astronauts who performed spacewalks outside Skylab, Shuttle and Mir.

The Apollo technical manuals explain that during Moonwalks and space walks, lunar astronauts wore a pressurized helmet (the inner goldfish-bowl transparent enclosure) inside an outer helmet. The inner helmet was made of Lexan, which is very tough and, most importantly, highly opaque to ultraviolet rays, which cause sunburns.



Figure 8.7-1. Harrison Schmitt's reflective visor is up and his face is in full sunlight in this frame from the Apollo 17 moonwalk TV broadcast.



Above: Figure 8.7-2. The live TV broadcast from which Figure 8.7-1 is excerpted [http://tiny.cc/w820dz].



On the right: Figure 8.7-3. A detail of a frame from the 16 mm film footage of the Apollo 11 moonwalk: Buzz Aldrin's face is in direct sunlight. Note the "Snoopy cap", the black and white cap that held the headset and microphones of the suit's radio.



Figure 8.7-4. Jerry L. Ross working outside the Shuttle Atlantis (1991). NASA photo STS037-18-032.



Figure 8.7-5. Mike Good spacewalking outside the Shuttle Atlantis, in full sunlight. NASA photo ISS023E047863.





Figure 8.7-6. Akihiko Hoshide working outside the International Space Station, 5 September 2012, with his face in direct sunlight. Source: NASA/Space.com.



Above: Figure 8.7-7. Alexander Gerst outside the International Space Station, with his reflective visor raised. Fonte: ESA/Instagram.

On the left: Figure 8.7-8. Jessica Meir photographs her reflection outside the International Space Station, with her reflective visor up. Source: NASA/Twitter, January 2020.

The outer helmet in turn had an inner visor, which further filtered ultraviolet and infrared radiation, and an outer visor (the gold mirror-like surface visible in many photographs) that filtered visible light (like mirror shades) to prevent dazzling and provided a further barrier to ultraviolet and infrared rays.[4]

Perhaps not unsurprisingly, these issues had been anticipated and solved during mission planning and suit design and had been tested during spacewalks in the early Apollo flights in Earth orbit, where sunlight is essentially as intense as on the Moon.

Basically, moonwalkers didn't get sunburned for the same reason why you don't get sunburned if you drive around in your car with the windows up: the transparent material

4 *Biomedical Results of Apollo*, Section 6, Chapter 6, *Pressure Helmet Assembly*.

allows visible light to get through but blocks the ultraviolet light that causes sunburns.

Astronauts, both on the Moon and in Earth orbit, often raise their golden visor when they are in shadow and sometimes don’t bother to lower it when they move back into sunlight, but in any case the multiple helmet layers still protect them against sunburn. The worst that can happen to them is that they are dazzled by the bright sunlight.

8.8 How come meteoroid showers didn't kill the astronauts?

IN A NUTSHELL: *Because big enough meteoroids are actually incredibly rare. The spacesuits and spacecraft had protective layers designed to absorb the impact of the minute specks that constitute the vast majority of meteoroids. There is no protection against larger meteoroids other than the very low probability of being struck, but this is an acceptable risk, as demonstrated by the fact that satellites, space probes, crewed spacecraft and the International Space Station don't get riddled by meteoroids.*

THE DETAILS: The Moon is pock-marked with craters produced by the constant crashing of *meteoroids*: rocky or metallic masses of all sizes that travel through space at speeds up to 80,000 kilometers per hour (about 50,000 mph).

Although the terms *meteor* and *meteorite* are often used, strictly speaking a space rock is a *meteoroid* when it travels through space: it becomes a *meteor* only if it punches into the atmosphere of a planet or moon and forms an incandescent trail and then becomes a *meteorite* if it reaches the surface of the planet or moon instead of disintegrating completely.

Looking at the Moon, it's understandable that someone might wonder how the moonwalkers could have possibly coped with this constant lethal danger. The answer is actually quite simple: they relied on probability.

Meteoroid showers aren't as frequent and dense as often depicted in Hollywood sci-fi productions. If they were, our fleets of satellites that provide us with weather data, TV programs and telephone calls would be destroyed all the time and the International Space Station would be Swiss cheese after over a decade in space. Several automatic probes have been traveling through deep space for three decades or more and have survived essentially unscathed.

Figure 8.8-1 shows a hole, produced by a meteoroid or by spacecraft debris, in the large solar panels of the Space Station. It's one of the very few impact holes detected in this orbiting outpost, despite the fact that when the picture was taken, in 2013, it had been in space for 14 years: according to NASA estimates, the hole measures about 6 millimeters (a quarter of an inch) in diameter and is probably due to a high-speed impact with an object measuring 1 to 2 mm (.04 to .08 inches) in diameter. Objects of this size are expected to hit somewhere in the large surface area of the Station roughly once every six months. Impacts with larger objects are even rarer.

Moreover, the Station orbits in a region of space close to Earth where there is artificial debris generated by many decades of satellite launches in addition to natural meteoroids. In deep space and around the Moon there is no such debris.

In addition, most meteoroids are literally microscopic in size. They have an enormous speed, but an almost negligible mass, so if a micrometeoroid strikes an astronaut it is stopped by the spacesuit's outer layers, which are designed for this purpose. The space suits used by the Apollo moonwalkers and the ones used today for work in space have essentially the same type of multilayer protection against micrometeoroids. That's one of the reasons why they're so bulky.

Non-microscopic meteoroids are quite rare. While the Moon's cratered surface might appear to suggest otherwise, one must bear in mind that those craters are the result of millions of years of exposure.

Accordingly, Apollo astronauts and all lunar spacecraft (including the Russian Lunokhod rovers) had a vanishingly small chance of being struck by a significant space pebble. The same applies to the more recent Chinese Chang'e and Yutu vehicles.

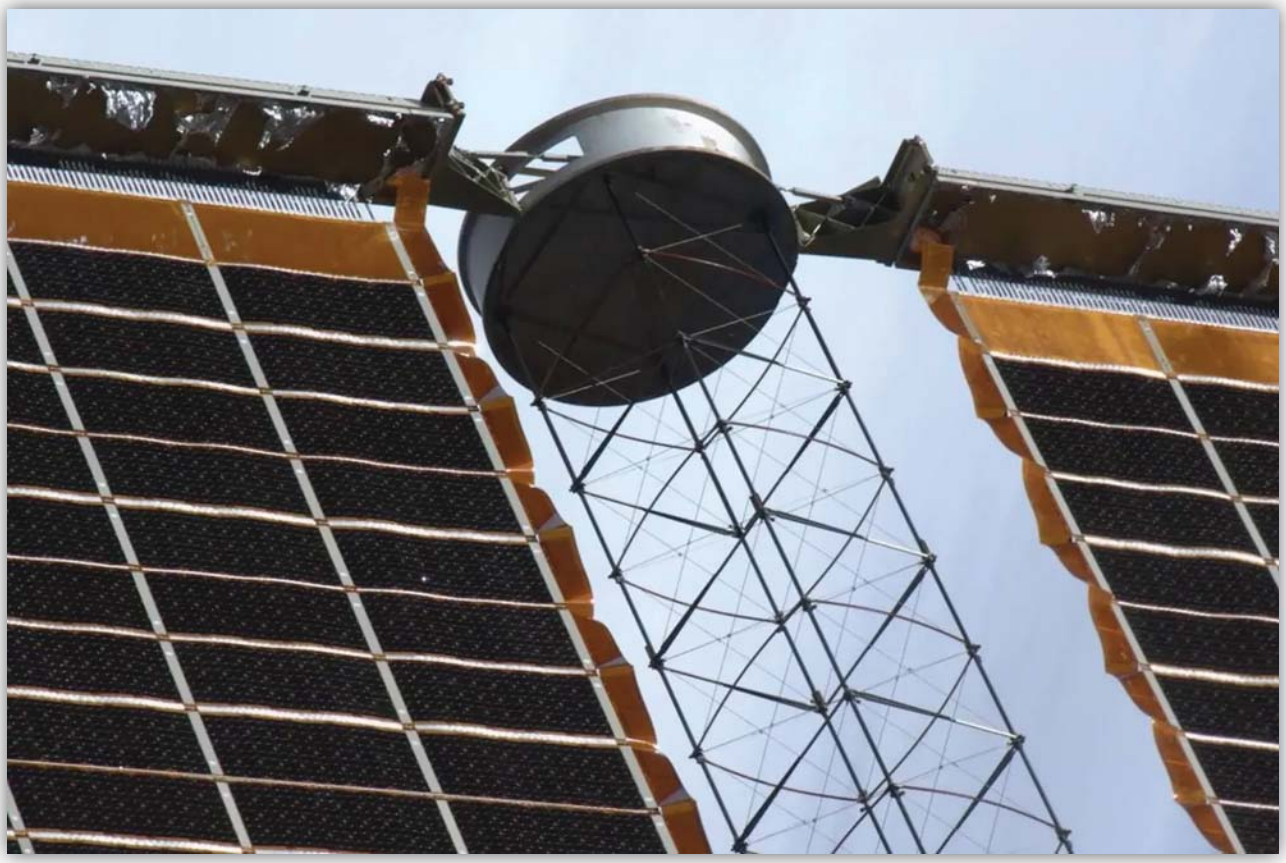


Figure 8.8-1. The tiny white dot is a rare impact hole in the large solar panels of the International Space Station. Credit: Chris Hadfield, 2013.

8.9 How could the astronauts have changed film magazines outside on the Moon?

IN A NUTSHELL: *Their cameras had light-tight magazines, designed to allow film changes even in direct sunlight and while wearing the spacesuit's bulky gloves, as shown in the TV transmissions from the Moon. This wasn't an exceptional technological innovation: the same feature was part of any professional photographer's equipment in the 1960s.*

THE DETAILS: Some Moon hoax theorists argue that astronauts on the Moon couldn't change the film of their cameras while wearing the clumsy, bulky gloves of their spacesuit and while they were in full sunlight, yet the mission records don't report that they ever went back into the lunar modules to reload their cameras. So how were they able to take thousands of photographs?



Figure 8.9-1. Snap-on mounting of a film magazine on a Hasselblad EL/M camera, similar to those used on the Moon. Lunar magazines were larger than the one shown. Credit: PA.

The answer is quite simple but clever: the films used for the Hasselblad cameras taken to the Moon were prepackaged in light-tight magazines that snapped onto the camera body (Figure 8.9-1) and were designed to be changed even in full sunlight. The same method was used by professional photographers of the time to change films even halfway through a roll.

Not all missions, moreover, changed films during their excursions outside the spacecraft. For example, the Apollo 11 moonwalk made do with a single magazine, so the problem didn't occur at all.



Figure 8.9-2. Charlie Duke is holding a film magazine and is about to change it outside on the Moon. Frame from the Apollo 16 TV transmission.

Handling the film magazines while wearing the thick gloves of a lunar spacesuit wasn't a problem because the magazines were cubic objects about 10 centimeters (4 inches) wide on each face (Figures 8.9-2 and 8.9-3).

Moreover, the magazines used on the Moon had been modified to have larger grip rings, so as to allow easy removal of the so-called *darkslide* (a removable metal lamina



Figure 8.9-3. Duke changes film magazine outside on the Moon during the Apollo 16 TV broadcast. Note that he reports that he tried to blow the dust off [http://tiny.cc/zf30dz].

designed to protect the film) even with gloves. This removal can be seen in the video of Figure 8.9-3.

Figures 8.9-4 and 8.9-5 show the darkslide ring of a commercial Hasselblad magazine and of a lunar magazine: the larger size of the ring to allow gripping it with spacesuit gloves is clearly visible.

In other words, changing films outside on the Moon was perfectly feasible and had been designed into the Hasselblad lunar cameras.



Figure 8.9-4. A standard Hasselblad magazine with its partially extracted darkslide. Credit: Ulli Lotzmann.

Charlie Duke's strange gesture

In the video shown in Figure 8.9-3, astronaut Charlie Duke removes the darkslide *before* mounting the magazine on the camera. This often perplexes Hasselblad camera experts, since the darkslide is usually removed only *after* the magazine has been installed, so that the film is not exposed to light. Removing it before mounting exposes the film to light, spoiling it. But Duke isn't wrong.

In the 1960s, darkslides were normally used in Hasselblads and other cameras that used a film magazine to protect the film from light. This allowed to change film mid-roll, without exposing any frames to unwanted light.



Figure 8.9-5. Magazine R of Apollo 11, currently displayed at the National Air and Space Museum in Washington, D.C. Note the larger ring used to pull out the darkslide while wearing spacesuit gloves. Credit: NASM.

Magazine changes were performed for example to install a Polaroid instant film magazine, take a test photograph with the camera already in position and set up, check the result and then mount a standard high-quality film magazine to take the final photograph.

At the time, cameras didn't have a video screen that could show the result of the photograph straight away and therefore a Polaroid was the only way to have a preview of the final photo and make sure that the camera was set up correctly.

But Charlie Duke's actions are correct, because lunar Hasselblads didn't use the darkslide for protection against light. They used it to prevent Moondust from contaminating the *reseau plate*, i.e., the glass plate that carried the cross-shaped markings that are visible in most Apollo photographs taken on the Moon.

This different use entailed that the portion of film that was visible during a magazine change would catch the light and become unusable. However, this wasn't a problem in the particular case of the lunar astronauts, who usually didn't need to change magazine mid-roll.

The astronauts, moreover, usually took three or four blank shots when they started and ended a magazine, so as to make the film advance and be sure to use a part of the film that had not been exposed to light inadvertently.

8.10 Isn't it impossible to cool an astronaut in a vacuum?

IN A NUTSHELL: *No, it isn't: if it were, then present-day spacewalks would be impossible too. You just have to transfer the astronaut's heat to the water reserve in their backpack and then discard the heated water. Exposing the water to the vacuum of space freezes it, removing even more heat from the astronaut's suit.*

THE DETAILS: People who are not familiar with spacesuit technology are sometimes puzzled by the idea of maintaining a comfortable temperature inside a thick, bulky insulating suit that is in the vacuum of space and goes from being exposed to full sunlight to being in total shadow, with consequent extreme temperature variations. A vacuum would seem to be an almost perfect insulation into which it might appear impossible to dump excess heat. It obviously rules out the use of a compressor like those used in air-conditioning units.

Yet Russian and American astronauts have been performing spacewalks since the 1960s and have since been joined by astronauts of many other countries, so clearly there must be a technology that allows to keep an astronaut cool in a vacuum, otherwise one would have to claim that every spacewalk ever made was faked (and still is, since spacewalks are routine events on the International Space Station).



Figure 8.10-1. Bruce McCandless performs the first fully untethered spacewalk while orbiting around the Earth in 1984 during Shuttle mission STS-41-B (NASA).

Many of these spacewalks didn't rely on *umbilicals* (long hoses that supplied air, power and temperature control to the suit) but used self-contained equipment located in the spacesuit backpack, so they were (and still are) very similar to the Apollo moonwalks.

If cooling an astronaut in a vacuum were really impossible, then this famous photograph would be impossible too (Figure 8.10-1). It shows US astronaut Bruce McCandless in space, *completely* untethered and disconnected from any cable or umbilical.

The photo shown in Figure 8.10-2 would likewise be impossible: it shows Italian astronaut Luca Parmitano

outside the International Space Station, retained only by a bracket that secures him by his feet to the Station's robot arm.



Figure 8.10-2. Luca Parmitano during his first EVA, in July 2013 (ESA/NASA).

Any doubters can simply read the technical literature (for example the book *US Spacesuits* by Kenneth S. Thomas and Harold J. McMann and *Russian Spacesuits* by Isaak P. Abramov and A. Ingemar Skoog) and realize that the necessary technology does indeed exist and was already available at the time of the Apollo flights, as described in the section entitled *PLSS (Portable Life Support System)* of the *Apollo Lunar Surface Journal*.

During lunar excursions, the heat generated by the astronaut's body was captured by a tight-fitting undergarment, known as *Liquid Cooling Garment*, in which water was circulated inside a web of fine tubing. This method is still used today for modern spacesuits and in some suits for racing car drivers and mechanics.[5]

The heated water then entered a heat exchanger, located inside the suit's backpack (Figure 8.10-3), where it released its heat to a water reserve of approximately four liters (8.5 pounds), which was increased to 5.2 liters (11.5 pounds) in later moonwalks.

5 This kind of undergarment was first used commercially in 1964 by NASCAR driver Paul Goldsmith. It enabled him to stay cool despite track temperatures of 54° C (130°F), as reported by *U. S. Spacesuits*, by Kenneth S. Thomas and Harold J. McMann on page 122.



Figure 8.10-3. The inside of an Apollo spacesuit backpack or PLSS, seen from the rear. Credit: Ulli Lotzmann/NASM.

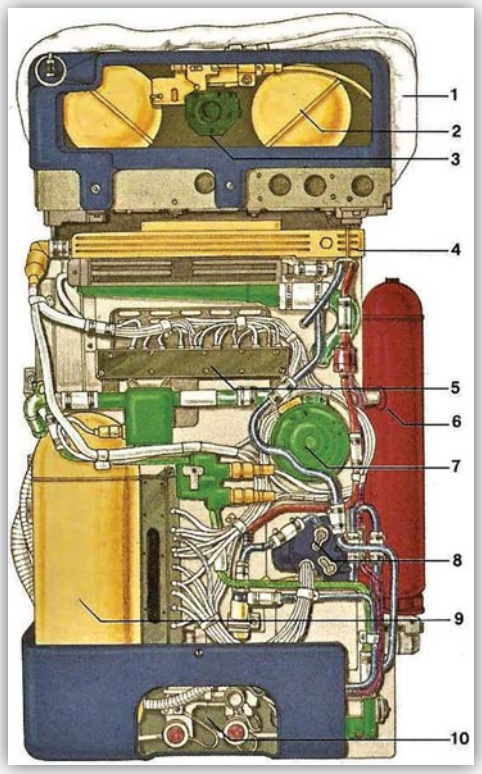


Figure 8.10-4. A schematic rear view of a backpack of an Apollo spacesuit, from the book Exploring Space by Kenneth Gatland (1983). 1) Oxygen purification system 2) High-pressure emergency oxygen reserve 3) Low-pressure oxygen 4) Radio 5) Electric junction box 6) Water circuit for thermal control 7) Ventilation circuit 8) Cooling liquid circuit 9) Primary oxygen subsystem 10) Water supply and dump valves.

This water then reached a *sublimator*, where it was slowly and gradually exposed to the vacuum of space. The consequent pressure drop, in accordance with the laws of physics, made its temperature fall: the water would freeze on the outer surface of the sublimator and turn directly from ice to water vapor, which was discharged through an appropriately provided duct.

This system allowed to dissipate up to 2,000 BTU/hour (approximately 580 W): enough to air-condition a small room and therefore more than adequate for cooling the inside of an astronaut's suit, so much that John Young, for example, remarked that even the intermediate setting made him feel freezing cold if he wasn't exerting himself.

8.11 How come there's no blast crater under the LM's engine?

IN A NUTSHELL: *Because there's not supposed to be one. The idea that the lunar module's engine should have formed a crater upon landing was suggested by some artist's illustrations published by NASA ahead of the Moon landings. But the crater is merely an artistic license: the engineers already knew that no crater would form because the Surveyor uncrewed probes had already landed and sent back pictures of their landing sites, which showed no crater under their engines.*

THE DETAILS: Conspiracy theorist Bill Kaysing argues that the Lunar Module mysteriously failed to blast a crater in the surface of the Moon with its powerful rocket engine.

> *NO CRATERS! [...] In all pictures of the LEM on the "moon", there is absolutely no evidence of a crater underneath the engine. If indeed the module had landed on the moon, the engine would have blasted out a substantial hole in the dustlike surface of the moon.*
>
> – *We Never Went to the Moon*, page 75.

Kaysing repeats the claim in the FOX TV documentary *Did We Land on the Moon?* (2001):

> *"The fact that there is no blast crater under the LM is one of the most conclusive pieces of evidence that I find supporting the hoax."*

But if a blast crater was expected, why would the alleged fakers be so clumsy as to forget to sculpt one into their lunar movie set?

Actually, the expectation of a blast crater under the LM was fostered by many artistic depictions of the Moon landing that were circulated by NASA and by the press ahead of the event, as witnessed for example by Figures 8.11-1 and 8.11-2.

But mission planners didn't really expect the LM engine to gouge a crater in the Moon: that detail, like many others in artists' illustrations, was dramatic license.

Artistic depictions are, well, *artistic*: they're not intended to portray an event with absolute fidelity, but to bring the event to life, explain it



Figure 8.11-1. The Moon landing as depicted by Norman Rockwell (1966). Credit: Eric Long, National Air and Space Museum, Smithsonian Institution.

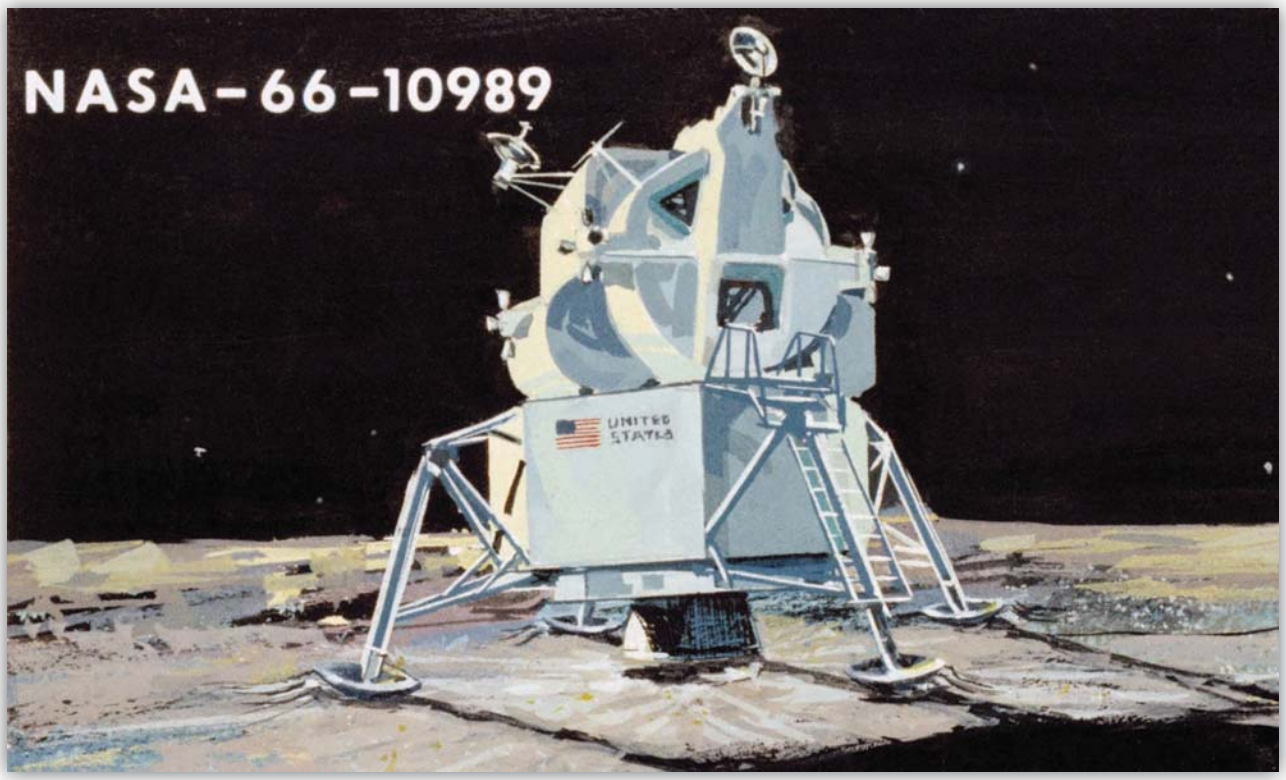


Figure 8.11-2. The Moon landing as depicted by NASA in 1966. Detail from S66-10989.

and communicate its significance, drama and excitement. If accuracy gets in the way of the message, it is often set aside.

For example, Figures 8.11-1 and 8.11-2 include stars, despite the fact that stars are normally not visible from the Moon when the lunar surface is in daylight, and the LM is shown without its characteristic protective "tin foil" (thermal blankets and micrometeoroid shielding), which in 1966 hadn't yet been added to the vehicle's design.

The crescent Earth in Figure 8.11-1 is likewise impossible, since the planet could only be lit in this way when the Sun is below the lunar horizon and therefore the moonscape should be in darkness; yet in Rockwell's exciting depiction the shadows suggest that the Sun is above the horizon and to the left.

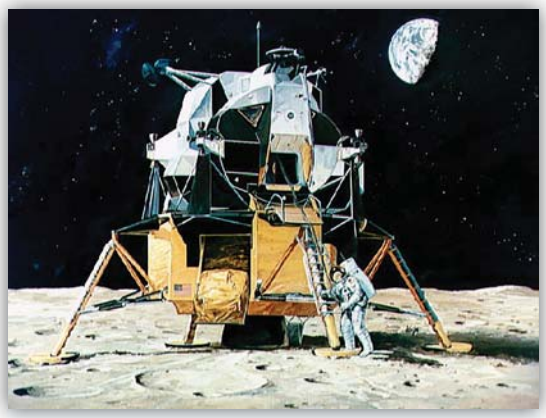


Figure 8.11-3. An artist's concept of the LM created for Grumman before the first Moon landing. NASA image S69-38662.

In other words, the presence of a crater under the LM in illustrations doesn't prove that the landings were faked: it proves the talent of the artist who found a way to suggest the dynamic action of the engine's exhaust in a static image. Essentially, Kaysing was mistaking artwork for hard science.

Actually, not all NASA illustrations show a crater under the Lunar Module. Figure 8.11-3 is an artist's concept created for Grumman (the company that designed and built the

LM), in which there's no blast crater and the LM is depicted far more realistically than in the previous figures (note, for example, the MESA equipment rack and the exhaust deflectors under the attitude control thruster quads). However, the stars are still shown in order to give depth to the artwork and the Earth is too low on the horizon for any Apollo landing site.

Leaving artistic license and conspiracy theories aside, why didn't the rocket blast of the LM form a crater or visibly disturb the surface? After all, the Lunar Module was a 15-ton spacecraft, so it needed a powerful engine to counter that weight and make it hover. Instinctively, we expect that kind of force to do some damage to the landing site.



Figure 8.11-4. Apollo 11's LM descent engine bell on the Moon. Note the dust-free, smooth, rocky surface in the foreground and the radial pattern formed on the surface by the engine exhaust. NASA photo AS11-40-5921.

But first of all, lunar gravity is one sixth of the Earth's, so the LM's weight on the Moon isn't 15 tons; it's 2.5. Moreover, these figures refer to the *initial* weight of the spacecraft, which decreased dramatically as its rocket fuel was used up. For example, for Apollo 12, which had an initial LM mass of 15,115 kilograms (33,325 lb), telemetry data reported the use of approximately 7,810 kilograms (17,200 lb) of propellant mass,[6] leaving a landing mass of approximately 7,305 kilograms (16,104 lb). The spacecraft essentially halved its initial mass by burning propellant, and in lunar gravity that residual landing mass is equivalent to a weight of just 1,217 kilograms (2,700 lb). In other words, keeping a LM in a hover above the landing spot entailed countering a weight of just 1,200 kilograms (2,700 lb), not 15,000 (33,000 lb); far less than assumed initially.

6 *Apollo 12 - The Nasa Mission Reports*, Apogee Books, 1999, p. 44 and p. 137.

Secondly, since the surface of the Moon consists of hard rock covered by a layer of dust, this rather modest rocket thrust would merely blow away the dust and expose the underlying rock. That's exactly what we see in the Apollo photographs (Figure 8.11-4).

The LM rocket exhaust might be expected to melt the lunar rocks at the landing spot, but the estimated temperature of the exhaust was approximately 1,500 °C (2,800 °F)[7] and decreased very rapidly because the hot plume expanded into a vacuum and therefore cooled down, like any other expanding gas.

7 *The Blast Crater*, Clavius.org.

Moreover, it takes several minutes of intense heat to melt the kind of rocks that form the surface of the Moon, whereas the LM's exhaust struck the same surface spot only for a few seconds. There simply wasn't enough heat or time to cause significant melting or cratering. What we do see in the Apollo photographs is a slight discoloration, possibly due to charring or to a chemical reaction of the propellant with the rock, and traces of fluid erosion.

No crater was expected by mission planners due to direct previous experience: seven automatic Surveyor probes had landed on the Moon between 1966 and 1968, sending back TV pictures of the landing site and chemical and physical tests of the lunar surface, which showed no cratering and indicated a compact rocky nature that allowed safe touchdown. The Apollo astronauts didn't fly into the absolute unknown; they had a fairly good idea of what to expect.

8.12 How could the timing of the lunar liftoff footage be so perfect despite the signal delay?

IN A NUTSHELL: *Because it was calculated in advance. Liftoff time was known to the second and the rate of ascent was known precisely, so the camera operator compensated the delay by tilting the camera up 1.3 seconds early with a predetermined rate of motion.*

THE DETAILS: In his *Wagging the Moondoggie* website, conspiracy theorist David McGowan considers with suspicion the spectacular TV footage of the liftoff of Apollo 15, 16 and 17 from the Moon. This footage was shot with the Rover's TV camera, which was controlled by radio signals from Earth.

Considering that the radio commands to move the camera took about 1.3 seconds to travel from the Earth to the Moon and the resulting TV picture took just as long to be received on Earth, how could the camera operator track the ascending Lunar Module? *"There apparently either wasn't any delay in the signal or NASA had the foresight to hire a remote camera operator who was able to see a few seconds into the future"*, argues McGowan.

Actually, the remote camera operator (Ed Fendell) *could* see more than a few seconds into the future, in a way, because the liftoff time of the Lunar Module was known very precisely in advance. Exact timing was critical, otherwise the LM would not be in the right place at the right time to rendezvous with the Command Module once in orbit around the Moon. The delay caused by the Earth-Moon distance was also known very precisely. So Fendell knew exactly when to send the commands: about 1.3 seconds ahead of the scheduled liftoff time.

The rate of climb of the LM was also known very precisely and therefore the rate at which the camera had to tilt up in order to keep the LM in frame could be calculated in advance and commanded in advance accordingly. The tilt rate depended on the distance of the camera from the LM and had to be calculated carefully.

The hard part wasn't calculating the exact timing of the commands, but their direction and speed, so as to take into account the distance of the Rover from the Lunar Module, as explained by Fendell himself in the video of Figure 8.12-1.



Figure 8.12-1. Ed Fendell, lunar TV camera operator, explains the techniques and challenges of obtaining video of the liftoffs from the Moon [http://tiny.cc/nm30dz].

The first attempt at this remarkable shot (during the

Apollo 15 liftoff) failed because the tilting mechanism malfunctioned and the camera didn't tilt up. The second attempt (Apollo 16) went better, but the Rover was parked closer than expected to the LM and this threw off the calculations, so the camera lost track of the LM quite early. The third attempt worked out perfectly, and Apollo 17's lunar liftoff was tracked until the LM became a tiny bright speck on the TV screen.

8.13 Why are Apollo 11's footpads clean while later missions have dusty ones?

IN A NUTSHELL: *Different terrains and different landing styles. Some missions landed in flat regions of the Moon and others landed in hilly areas, with different dust covers. Some pilots landed less gently than Apollo 11; some dragged their footpads on the ground, scooping up dust. The astronauts also occasionally kicked dust into the footpads as they walked close to the LM landing gear.*

THE DETAILS: While Apollo 11's Lunar Module landing gear is immaculately dust-free, the footpads of other lunar modules are very dusty. Compare, for example, Figure 8-13.1 (Apollo 11) with Figure 8-13.2 (Apollo 16).

So what, you might say. But according to some doubters, this is important. Such a conspicuous difference allegedly proves that Apollo 11 was faked badly (forgetting to sprinkle dust on the footpads) but later missions were staged more accurately, correcting this omission.

Once again, a conspiracy theory is based on the assumption of bungling perpetrators: for some bizarre reason, the most important fakery of the century was assigned to a bunch of



Figure 8.13-1. A very clean Apollo 11 LM footpad. NASA photo AS11-40-5920 (cropped).



Figure 8.13-2. A dusty Apollo 16 LM footpad. NASA photo AS16-107-17442 (cropped).

sloppy amateurs who made all sorts of mistakes and left evidence in the photographs, and somehow their bosses didn't notice the mistakes before releasing the pictures to the public.

Moreover, this kind of theory is also a typical example of how conspiracy theorists focus on absolutely trivial and insignificant detail and present it as some kind of devastating evidence of fakery, instead of considering the most obvious and simple answer: the dust is different because the various spacecraft landed in geologically different places.

They did so in order to acquire the broadest possible variety of samples: Apollo 11 and 12 landed on very flat terrain; Apollo 14 touched down in a broad, shallow valley; and Apollo 15, 16 and 17 landed in the highlands of the Moon.

It doesn't take a degree in geology to realize that the Moon isn't the same all over. It's not some sort of giant, uniformly dusty billiard ball. Even with the naked eye it is possible to distinguish darker regions, which are the lunar plains, and brighter mountainous areas, with different colors and made of different rock. Some regions will have more surface dust than others.



Figure 8.13-3. Composite panorama of the Apollo 11 landing site (photos AS11-40-5930/31/32/33/34/39/40). Credit: NASA/Moonpans.com.

Compare, for example, the Apollo 11 site (Figure 8.13-3)

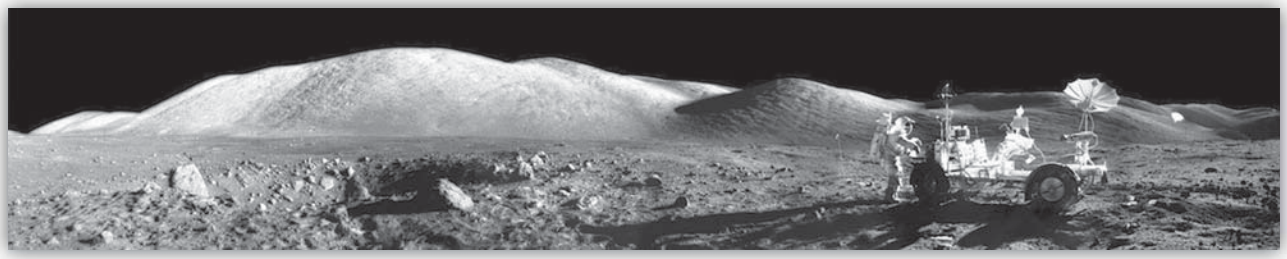


Figure 8.13-4. Composite panorama of the Apollo 17 landing site. Credit: NASA/Moonpans.com.



Figure 8.13-5. Another composite panorama of the Apollo 17 landing site. Credit: NASA/Moonpans.com.

with the Apollo 17 site (Figures 8.13-4 and 8.13-5).

It seems reasonable to assume that vastly different locations might have different dust coverings. Indeed, Pete Conrad (Apollo 12) and Dave Scott (Apollo 15) reported that they had to fly on instruments for the final 30 meters (100 feet) of their landing because the dust kicked up by their engine's exhaust obscured their view of the surface, while other LM pilots didn't have the same problem.

Moreover, some landings were quite rough. Apollo 11 landed very smoothly after hovering and blowing away most of the local dust, but Apollo 14, for example, dragged its landing gear sideways after touchdown. This caused the footpads to scoop up moondust, as shown for example in NASA photo AS14-66-9234 (Figure 8.13-6).

Apollo 15 landed with one footpad in a 1.5-meter (5-ft) deep crater, damaged its engine exhaust bell and came to rest at a steep angle. Its footpads dug quite deeply into the ground and got very dusty.

Finally, dust could also accumulate on the footpads after landing, for example if the astronauts worked close to the LM's landing gear (as in Figure 8.13-2). As they walked around, they kicked up dust which, in a vacuum and in low gravity, could travel quite far and end up on the footpads.



Figure 8.13-6. An Apollo 14 footpad shows considerable dust displacement. NASA photo AS14-66-9234.

8.14 How can there be no dust at all on Apollo 11's LM footpads?

IN A NUTSHELL: *It was blasted away. Dust moved by a rocket exhaust in an airless environment such as the Moon doesn' billow up around the spacecraft and then settle on it: it travels in straight lines away from the vehicle, unhindered by any air resistance, and therefore is unlikely to end up on the vehicle's footpads.*

THE DETAILS: Photographs of Apollo 11's lunar module footpads on the Moon show them to be completely dust-free (Figure 8.14-1). To some this seems suspicious. Shouldn't the engine blast have blown at least some dust onto the footpads? Says Bill Kaysing in the 2001 documentary *Did We Land on the Moon?*:

> *"If they had truly landed on the Moon, this dust would have then descended on the lunar lander, on the footpads, and we find not a trace of dust on the footpads."*

However, the lack of dust on the footpads doesn't prove that the spacecraft was actually a mockup delicately placed on a movie set and that the hoax perpetrators incredibly forgot



Figure 8.14-1. A spotless Apollo 11 footpad. NASA photo AS11-40-5920 (cropped).

to spread some dust on the footpads to make the scene more realistic. There's a simpler, entirely non-conspiratorial explanation: on the Moon, dust doesn't *"descend"* as Kaysing suggests, simply because it doesn't rise and float in the first place.

The Moon is airless, so there's no atmosphere to carry the dust and allow it to form billowing clouds that then settle. The dust simply gets blown sideways and outward, racing roughly parallel to the ground and away from the landing spot, and then falls down at the end of its essentially rectilinear trajectory, without floating around. This effect is clearly visible in the footage of the Apollo lunar landings and liftoffs.

Moreover, in a vacuum only the dust that is struck *directly* by the exhaust gets moved, and the exhaust expands very rapidly and just as rapidly weakens, so the displacement is very localized (on Earth, such a displacement has a broader action because the exhaust displaces the surrounding air, which in turn displaces dust, spreading out the effect). Indeed, the Apollo 11 photographs show pebbles and dust a short distance out from the footpads, as evidenced in Figure 8-14 by the footprints behind the LM's landing gear.

The dust that is moved, however, can travel quite a distance at high speeds, since there's no air resistance to slow it down and the low gravity drags it down more gradually than on Earth. On Apollo 12, dust displaced by the LM exhaust reached the Surveyor probe, roughly 200 meters (650 feet) from the LM, as evidenced by the sandblasting detected on the side of Surveyor that faced the LM.[8]

8 *Watch Out for Flying Moondust*, by Trudy Bell and Dr. Tony Phillips (2007), Nasa.gov.

8.15 How can the astronauts' footprints be so sharp?

IN A NUTSHELL: *They're as sharp as they should be in dry, jagged, electrostatically charged moondust in a low-gravity vacuum, which behaves quite differently than weathered sand in Earth's atmosphere and gravity.*

THE DETAILS: In *NASA Mooned America!,* Ralph Rene claims that *"clear tracks in deep dust require moisture; otherwise they form only indistinct depressions [...] There can be no moisture on the Moon [...] And yet, every picture allegedly taken on the Moon shows clear footprints"* (page 7). In other words, sharply outlined bootprints such as the famous one shown in Figure 8.15-1 are said to be impossible on the Moon.

Proponents of this claim, however, fail to consider that sand on Earth is exposed to very different conditions than dust on the Moon.

First of all, on Earth, the wind, the flow of water and other natural phenomena constantly move and churn the grains of sand against each other, smoothing their surfaces and reducing their friction. On the Moon this smoothing doesn't occur, and therefore the grains of lunar "sand"



Figure 8.15-1. A bootprint left on the Moon by Buzz Aldrin (Apollo 11). Detail of photo AS11-40-5877.

(termed *regolith* in geological jargon) are sharp-edged and uneven. Accordingly, they tend to lock together and stick to each other far more than Earth sand, much like a stack of smooth river stones will collapse easily while a similar pile of jagged rocks will keep its shape. This leads to higher cohesion and sharper footprints.

Then there's gravity, which is one sixth of the Earth's. Stacked moondust particles are pulled down by weaker forces than on our planet and therefore the edges of footprints, for example, hold their shape more easily.

Finally, there's electrostatic attraction. Lunar regolith has a considerable electrostatic charge and therefore its grains tend to cling to each other more than ordinary Earth sand, in the same way that dust clings to an electrostatically charged glass surface, such as an old-style (CRT) television screen.[9]

These differences, therefore, allow lunar regolith to form far sharper prints than sand on Earth. This is confirmed independently by the images of lunar soil sent by the Soviet Lunokhod rovers, which show finely detailed wheel tracks (Figure 8.15-3).

9 *Effects of gravity on cohesive behavior of fine powders: implications for processing Lunar regolith*, Otis R. Walton, C. Pamela De Moor and Karam S. Gill, in *Granular Matter,* vol. 9 no. 6 (2007).



Figure 8.15-2. Aldrin leaves another bootprint in the very fine lunar dust during Apollo 11. Detail of photo AS11-40-5880.

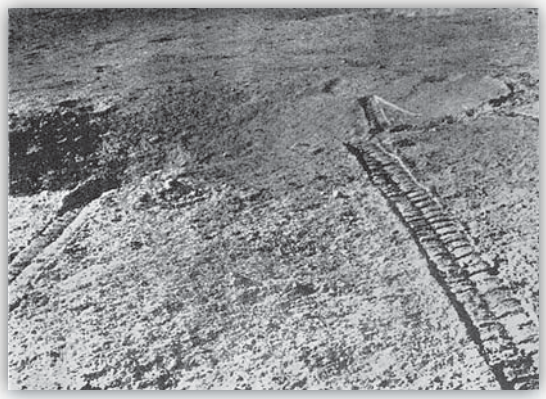


Figure 8.15-3. Sharp-edged wheel tracks left on the Moon by Soviet Lunokhod 1 in 1970.



Figure 8.15-4. The bootprint produced in vacuum in synthetic regolith by Mythbusters*.*

As further confirmation, in 2008, the *Mythbusters* TV show placed a sample of powdery material, geologically equivalent to lunar regolith, in a vacuum chamber and then pressed a footprint into it, using a replica of an Apollo Moon boot. The result closely resembled the sharp-edged footprints seen in Apollo photographs, despite the six times stronger gravity and the lack of any significant electrostatic charge (Figure 8.15-4).

8.16 Wasn't the lunar module hatch too narrow?

IN A NUTSHELL: *No, it wasn't. People who claim that the spacesuit was too wide to pass through the hatch are referring to the width of the suit when spread flat and with the arms at its sides, but the suit is much narrower when worn. Also, the moonwalkers crawled through the hatch on all fours and therefore with the arms tucked under their bodies, not at their sides. All this greatly reduced the actual suit width, allowing it to pass easily through the hatch. Besides, if the whole thing had been faked, it would have been trivial to fake a comfortably bigger LM hatch.*

THE DETAILS: James Collier, author of the book and DVD *Was It Only a Paper Moon?*, reported that he went to the National Air and Space Museum in Washington and the Johnson Space Center in Houston, where he

> *video taped an actual LM. Here research indicated that the crew compartment and hatches were too small for the astronauts to actually enter and exit. After taking the video footage I challenged NASA to prove that two six-foot astronauts, in ballooned-out pressure suits (4-psi in a vacuum) could either get in or get out of a LM.*

Mary Bennett and David Percy, in their book *Dark Moon* (pages 340-341), argue that

> *...the aperture of the LM is only 32 1/4 inches wide [...]. Surely, it would be very difficult for a pressurised, spacesuited astronaut, fully loaded with his PLSS and measuring over 31 inches in width to exit through such a small and awkward aperture.*

The width of the LM hatch quoted by Bennett and Percy is essentially correct, as confirmed by NASA's *Apollo 11 Press Kit* and *Lunar Module Operations Handbook.*

However, their measurement of the width of a suited astronaut is definitely wrong, because it refers to the spacesuit laid flat and with its sleeves at the sides of the flattened torso of the suit (as shown in the photograph on page 341 of *Dark Moon*). Any garment measured in this way will appear to be much wider than when it is being worn, because it's not wrapped around the wearer's body. Try this for yourself: your sweater, when spread flat, is much wider than your body. Basically, Bennett and Percy are confusing girth and width.

The PLSS backpack was approximately 51 centimeters (20 inches) wide and therefore posed no problems in terms of hatch width.

This mistake is compounded by the fact that the Apollo astronauts crawled out through the hatch on their hands and knees and therefore held their arms tucked in under their bodies, not at their sides as shown in *Dark Moon*. This reduces further the actual width of the spacesuited astronaut.

Besides, Apollo photographs such as AS11-40-5862 (Figure 8.16-1), which shows Buzz Aldrin as he exits the lunar module through the hatch, clearly demonstrate that the hatch was wide enough. Astronauts reported that exit certainly wasn't easy, but it was feasible.

There's a very simple way to check all this. The hatch width reported by Bennett and Percy, 32 1/4 inches (82 centimeters), is the width of an average interior house



Figure 8.16-1. Buzz Aldrin exits from the Lunar Module to walk on the Moon. NASA photo AS11-40-5862 (cropped), taken by Neil Armstrong.

door. The widest part of a suited astronaut's body is at the shoulders, so try standing in a doorway and notice how much clearance you have on either side. Even if you take into account a bulky Apollo spacesuit, there's still room enough to walk through easily.

If you really want to be thorough, buy or rent a replica Apollo spacesuit (available from specialist dealers), put it on and compare its actual width with the hatch of an original LM, such as the ones on display at the National Air and Space Museum in Washington, DC, at the Kennedy Space Center in Florida or at the Johnson Space Center in Houston, Texas.

While it may seem impossible to access priceless museum artifacts like the Lunar Modules to measure them, today's technology actually allows this without even getting too close. A 2018 article on Metabunk.org describes how the LM on display at the Kennedy Space Center, which is an unflown original vehicle, was measured remotely using a home-made portable LIDAR scanner. The same technique was then used on an Apollo spacesuit worn by a manikin and displayed at the KSC. This method allowed not only to measure the various widths but also to create a digital model of the interaction between the suit and the LM. The result is that the suit fits through the hatch. All the data are publicly available.



Figure 8.16-2. LIDAR acquisition of the dimensions of the hatch and of the spacesuit [http://tiny.cc/mc40dz].

The Metabunk article notes that some conspiracy theorists even claim that the astronaut manikins placed next to the Lunar Module at the Smithsonian are smaller than real people to hide the fact that the hatch is (allegedly) too small.

There's another logical rebuttal to any claim of an impossibly narrow hatch or cramped LM interior: if the whole Apollo project was faked, there would have been no point in skimping on the size of the spacecraft. Why not simply fake a slightly bigger LM with a wider hatch and avoid any questions about hatch size?

8.17 How come the pressurized spacesuits don't look like they're inflated?

IN A NUTSHELL: *Because they had an inner pressure containment layer, just like present-day spacesuits, and the outer layer wasn't pressurized.*

THE DETAILS: Some Moon hoax proponents wonder how astronauts could flex their fingers inside the bulky gloves of their spacesuits and more generally how they could move at all, since the suits, if pressurized as NASA claims, would have inflated like balloons in the vacuum of space and would have become impossibly rigid. Yet Apollo photographs show astronauts on the Moon moving around quite comfortably, with suits that show no sign of ballooning and are actually flexible and surprisingly creased and saggy.

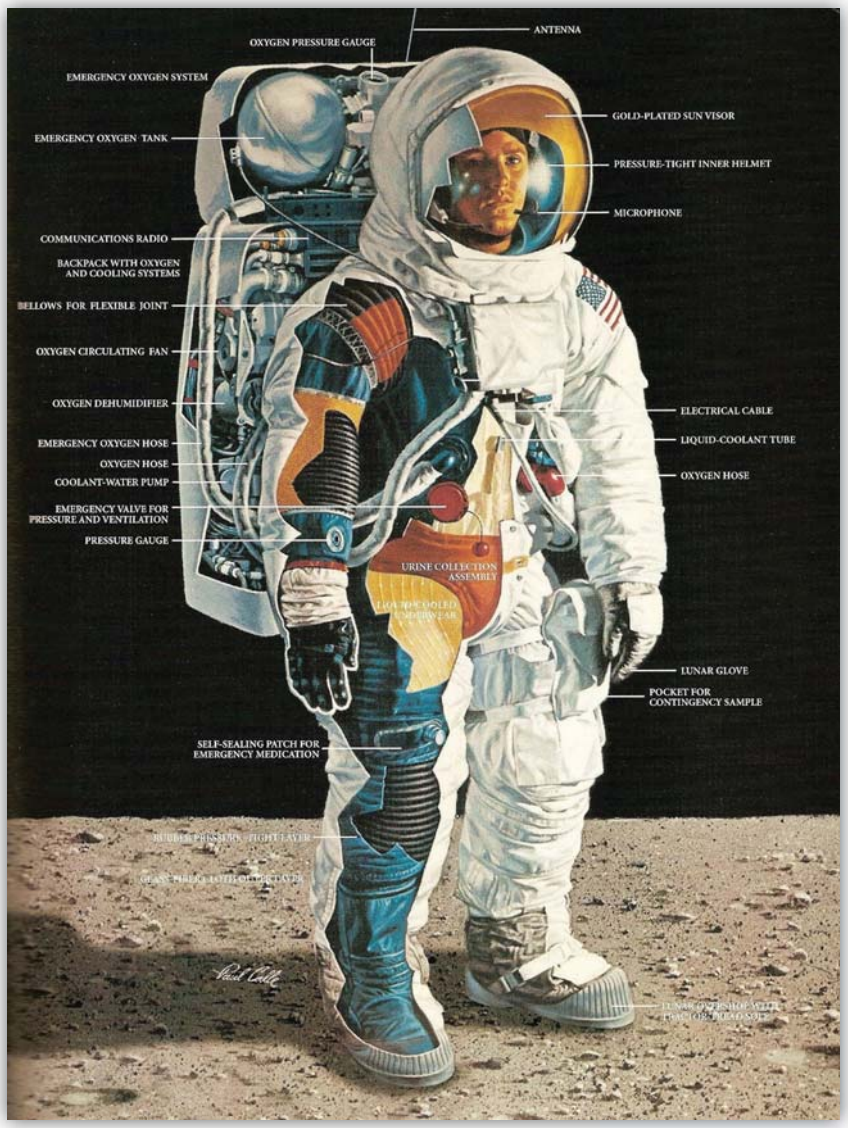


Figure 8.17-1. Artist's illustration of a cutout of a complete spacesuit (pressurized inner suit and unpressurized outer suit). Credit: Paul Calle.

This objection can be dismissed simply by considering that the American, Russian and Chinese spacesuits currently worn today by astronauts during spacewalks on the International Space Station and in Chinese spaceflights are quite obviously flexible and don't balloon, and neither did the suits used in Skylab or Shuttle flights or by cosmonauts aboard Soyuz spacecraft or the Mir space station, so there must be a way to solve these allegedly unsurmountable problems. That way is essentially the same one introduced by Russian and American spacesuits of the 1960s.

The issue is probably based on limited knowledge of the actual structure of Apollo spacesuits. Each suit was in fact composed of *two* suits, worn one inside the other: a pressurized inner suit (shown in blue in Figure

8.17-1), rarely seen on its own, and an unpressurized outer one (shown in white in the same figure), which is the one visible in all the Apollo moonwalk photos.

The inner suit, known as *Pressure Garment*, was the airtight part of the suit that enclosed the astronaut's body. It was pressurized to approximately one third of sea-level pressure; this helped to reduce the suit's tendency to balloon and stiffen. It was mostly made of neoprene in which a non-elastic containment layer of mesh was embedded.

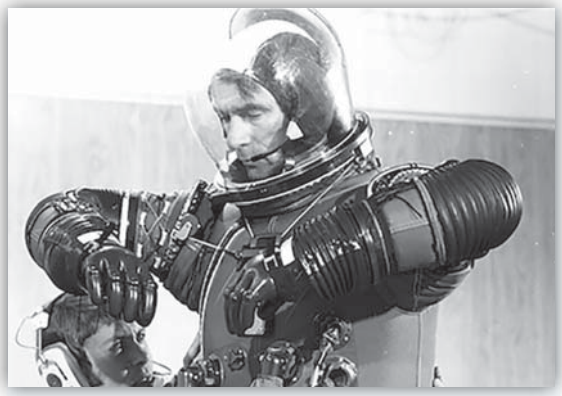


Figure 8.17-2. Gene Cernan checks the fit of the airtight inner layer of the Apollo spacesuit, known as Pressure Garment*. Note the accordion-like joints at the elbows and fingers. NASA photo AP17-72-H-253.*

In other words, the inner suit could only expand until this mesh was taut. If you can imagine a balloon placed inside a bag of netting, or if you look at a garden hose, you have a good example of a pressure containment layer.

The fingers, shoulders, knees and elbows of the suit had accordion-like joints that allowed flexing without ballooning (Figures 8.17-2 to 8.17-5).

The outer layer, shown in Figure 8.17-6, was made of fireproof, abrasion-resistant materials and was designed to provide thermal insulation

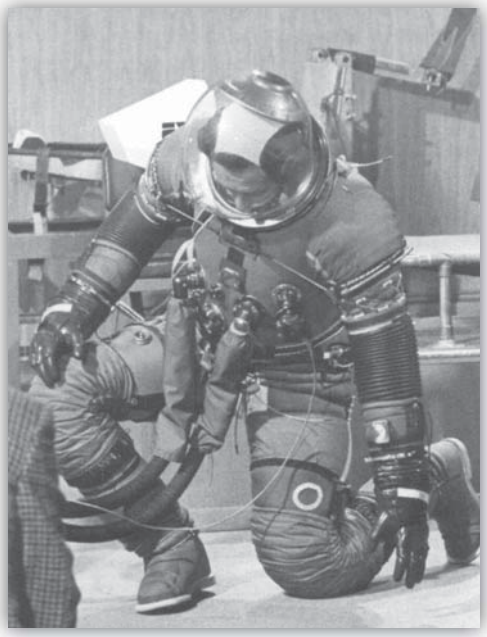


Figure 8.17-3. Charlie Duke (Apollo 16) tests the flexing of his Pressure Garment*.*



Figure 8.17-4. A color photograph of the Apollo Pressure Garment*.*



Figure 8.17-5. Apollo 17 astronaut Harrison Schmitt tests the Pressure Garment*.*



and protection against *micrometeoroids*, microscopic specks of dust that travel through space at enormous speeds and strike the astronauts on the lunar surface like minute bullets, which are stopped by the multiple layers of the outer suit.

In summary, the Apollo spacesuits don't look like they're pressurized simply because what we normally see is their outer layer, which indeed wasn't pressurized.

Figure 8.17-6. Ron Evans (Apollo 17) checks the maximum upward reach of his arm while wearing both the inner Pressure Garment *and the white outer protective suit.*

8.18 How could the astronauts still send TV to Earth when their directional antenna wobbled?

IN A NUTSHELL: *Because the antenna had ample pointing tolerances and its signal still reached Earth even if this pointing shifted a little. Incredibly sensitive giant antennas on Earth were ready to pick up even a slightly attenuated signal.*

THE DETAILS: During the Apollo moonwalks that used the Lunar Rover electric car, communications between the astronauts and the Earth and TV transmissions from the Moon were sent through the car's transmitter. The Rover was



Figure 8.18-1. Top center: the parabolic dish antenna of Apollo 17's Lunar Rover. Left: the remote-controlled TV camera. Photo AS17-134-20475.



Figure 8.18-2. Right: the Rover points its antenna toward the Earth while an astronaut works close to the Lunar Module (left) during Apollo 17. Detail of photo AS17-134-20435.

equipped with a parabolic antenna which had to be pointed precisely toward the Earth.

According to some Italian conspiracy theorists (Luogocomune.net; Giuseppenardoianni.it), this configuration should have caused interruptions of the signal when the parked car wobbled because it was touched by the astronauts and therefore was no longer exactly pointed at the Earth. However, they say, the recordings of the TV broadcasts don't show any such signal breaks.

Actually, the NASA manuals referenced by these theorists include a key technical detail which they somehow failed to mention: the antenna could be off-center up to 10° without causing excessive attenuation of the signal.

For example, the *Crew Training Manual - Lunar Communications Relay Unit*, on page 21, describes the parabolic antenna (known as *High Gain Antenna* or *HGA*) by noting that it has a diameter of approximately 92 centimeters (three feet) and a *gain* (in this context, a indicator of signal strength) equal to 24 dB when centered on Earth, 23.5 dB within 5° and 20.5 dB within 10°. Specifically:

> *The antenna gain is nominally 24 db on boresight, 23.5 db over a 5° cone and 20.5 db over a 10° cone.*

Accordingly, any oscillation of the Rover of up to 10° would have caused an *attenuation* of the signal but would not have make it miss the Earth completely. The weaker signal would still have been picked up by the giant 64-meter (210-ft) dish antennas on Earth.

Moreover, it's not true that there are no breaks in the TV transmissions. Researcher Diego Trystero published a video (Figure 8.18-3) which assembles some of the many conspicuous interruptions that occurred during live transmissions from the Moon, often in relation to oscillations of the vehicle.



Figure 8.18-3. A collection of TV signal loss episodes during Apollo 15, 16 and 17 [http://tiny.cc/fh40dz].

9 Other alleged anomalies

Conspiracy theorists don't stop at claiming that the photographs are doctored or that the Apollo spacecraft couldn't reach the Moon. They allege that people who were involved in the Apollo program were murdered to keep them quiet and that crucial historical records have been faked or hidden. They also claim that the astronauts were unable to conceal their guilt for taking part in the conspiracy. This chapter deals with these grim allegations.

9.1 Why did the astronauts have guilty looks on their faces and shun public appearances?

IN A NUTSHELL: *They didn't. Their expressions are not* guilty, *but* serious*. Hoax theorists cherry-pick the photos in which the Apollo astronauts are serious and solemn and claim that they always had that expression because they felt guilty of their deception. Actually, there are plenty of photographs and film clips in which they smile, joke and laugh. They didn't shun public appearances: they held countless public talks, TV appearances and were even involved in a few movies. They also wrote very candid autobiographies.*

THE DETAILS: It is often argued that Armstrong, Collins and Aldrin had suspiciously gloomy, guilty, sad and reluctant expressions as they were held in quarantine after their Moon trip (Figure 9.1-1).

But there's a good reason why they're serious in that quarantine photo: they're listening to President Nixon's formal speech, so it would have been rather inappropriate for them to be laughing their heads off. Once Nixon changes to a less formal tone, the astronauts smile and laugh with him (Figures 9.1-2 and 9.1-3).



Figure 9.1-1. The apparently gloomy expressions of Armstrong, Collins and Aldrin (Apollo 11) as they meet US President Nixon on the first day of their post-flight quarantine.

The Apollo 11 astronauts also look quite at ease during their preflight press conference.

Likewise, the expressions of the Apollo 12 astronauts in quarantine are anything but gloomy.



Figure 9.1-2. The Apollo 11 astronauts laugh with Nixon.



Figure 9.1-3. Another photo of the same event. The astronauts and the President are all laughing. Detail of photo S69-21365.



Figure 9.1-4. Aldrin, Armstrong and Collins during the Apollo 11 preflight press conference.



Figure 9.1-5. Left to right: Pete Conrad, Dick Gordon and Alan Bean, the crew of Apollo 12, cheer from their quarantine after returning from the Moon.

The Apollo 11 post-flight press conference

Conspiracy theorists and ordinary doubters often mention the press conference held by the Apollo 11 astronauts after returning from the Moon, noting how their expressions are once again gloomy and seem to betray unease. The astronauts utter their words very slowly, with an almost flat tone, as if they were speaking grudgingly. This, it is claimed, is evidence that they are lying uncomfortably.



Figure 9.1-6. A frame from the footage of the Apollo 11 post-flight press conference.

Actually, if you watch the entire press conference (Figure 9.1-7) instead of just its first few minutes, it becomes evident that the three astronauts gradually relax and become more at ease while still choosing their words very carefully. There are many

moments of laughter, smiles and outright jokes despite the pressure of it being their first press conference after their historic trip. Here's an example from 37:53 in the video of Figure 9.1-7:

> *Reporter: Was there ever a moment on the Moon where either one of you were just a little bit spellbound by what was going on?*
>
> *Neil Armstrong (grinning): About two and a half hours!*

Their moonwalk had in fact lasted two and a half hours in all.



Figure 9.1-7. Full version of the Apollo 11 post-flight press conference [http://tiny.cc/15k6dz].

In other words, the gloomy still image shown by conspiracy theorists has been intentionally selected to give the wrong impression that the astronauts were deeply uneasy. Figure 9.1-8 is a different still from that same press conference: all three astronauts are smiling. Figure 9.1-9 is a sampling of some of the quips and jokes that the Apollo 11 astronauts made during the press conference.



Figure 9.1-8. Another still from the Apollo 11 post-flight press conference gives a far less grim impression.

Nevertheless, it has to be noted that almost all the Apollo astronauts were test pilots, unaccustomed to the glare of the media spotlight and trained, like all pilots when they have to report on their flight, to speak clearly and precisely, measuring their words. They were also tired not only from the trip to the Moon but also from the subsequent quarantine. They acknowledge their limited media skills even in this post-flight press conference when the discuss the Goodwill Tour that will take them around the world, visiting kings and presidents of many countries:



Figure 9.1-9. A selection of quips, smiles and jokes from the same press conference [http://tiny.cc/ayl6dz].

> *Reporter: Gentlemen, you're about to take some tours. I wonder what your feelings are. Is that perhaps the most*

> *difficult part of the mission or are you looking forward to it?*
>
> *Armstrong: It's certainly the part that we're least prepared to handle!* [laughter from the audience]

There's also another practical aspect to be considered when watching this 1969 press conference with today's eyes: in those days, portable recorders were rare (only one can be glimpsed in the huge crowd of reporters in the video) and therefore journalists had to write down, sometimes in shorthand, what the astronauts said. The official recording of the event would be released only after it had been duplicated, and this would have taken hours with the analog systems of the period, whereas reporters had to go to press as soon as possible.

Accordingly, the astronauts spoke very clearly and slowly to allow everyone to transcribe correctly and also to choose their words very carefully, since they were quite aware of the great historical importance and of the political sensitivity of everything they said. They were, after all, the first human beings in all of mankind's history to go to the Moon and back.

Moreover, if Armstrong, Aldrin and Collins had instead been at perfect ease and as cheerful as talk show hosts, moon hoax believers would probably argue that this would prove that they were actors.

Media appearances

Anyone who claims that the Apollo astronauts were reclusive and reluctant to appear in public probably is not aware of the various Goodwill Tours mentioned above: the Apollo 11 crew Tour, for example, visited 23 countries in 37 days and was seen by roughly 100 million people.

Contrary to the claims made by some conspiracy theorists, the other lunar astronauts also were anything but sad and guilty-looking after their flights. Over the decades they have been (and still are) part of countless public talks and television events, as well as movies and documentaries. They have also written about their experiences in their often quite candid autobiographies. Far from shunning the crowd, they have promoted space exploration in many ways, including some unorthodox ones.



Figure 9.1-10. Astronaut Buzz Aldrin is on ABC's Break the Bank *(1976).*

Buzz Aldrin, for example, in 1976 was on ABC's *Break the bank*; he appeared very



Figure 9.1-11. Aldrin records a rap with Snoop Dogg (2009) [http://tiny.cc/n3l6dz].



Figure 9.1-12. Astronaut Jim Lovell with David Bowie on the set of The Man Who Fell to Earth *(1976).*

light-heartedly on *Da Ali G Show* (2003), recorded a rap song with Snoop Dogg (*Rocket Experience*, 2009), was a contestant in the 2010 edition of the US show *Dancing with the Stars* and guest-starred in TV shows like *30 Rock* (2010)*, Numb3rs* (2006) and *The Big Bang Theory* (2012), as well as in the movie *Transformers - Dark of the Moon* (2011); his many interviews and appearances include CBC's *Beyond Reason* (1977), Conan O'Brien's *Conan* (2013), ITV's *Lorraine* (2016), *The Late Show with Stephen Colbert* (2016), as well as documentaries such as *In the Shadow of the Moon* (2007). In his autobiography, *Magnificent Desolation*, he has also acknowledged very openly his successful fight against alcohol and depression.

Jim Lovell (Apollo 8, Apollo 13), too, has made a few movie appearances, for example as himself in Nicolas Roeg's *The Man Who Fell to Earth* (1976) next to David Bowie and as captain of the ship that recovers the astronauts in Ron Howard's *Apollo 13* (1995).

Neil Armstrong's appearances were so many that they require a separate section of this book.



Figura 9.1-13. Figure 9.1-13. Jim Lovell, with his back to the camera, wears a US Navy captain's uniform to welcome actor Tom Hanks (who plays Lovell) at the end of the movie Apollo 13 *(1995) [http://tiny.cc/sbm6dz].*

A special mention goes to Alan Bean, Pete Conrad and Richard Gordon, whose video *Apollo 12 Uncensored* is a hilarious collection of anecdotes and jokes about their lunar landing that certainly doesn't appear to suggest guilt or unease.

This Moon hoax claim is probably one of the most significant: it shows very clearly the symptoms of a world vision in which everything, even an ordinary, occasional serious expression, is interpreted as evidence of a colossal conspiracy and the facts are cherry-picked to bend them to that distorted vision.



Figure 9.1-14. Apollo 12 Uncensored *spends 45 minutes with the Apollo 12 astronauts candidly talking about their mission, showing how much they enjoyed it and were awed by it. At 24:26 they talk about the* Playboy *photos smuggled to the Moon; at 26:00 they discuss their Hasselblad timer prank [http://tiny.cc/bem6dz].*

9.2 Did Neil Armstrong hide from the media out of guilt?

IN A NUTSHELL: *No, he simply picked his media appearances very carefully after the overwhelming barrage of public events that followed the Moon landing. He preferred technical conferences, in which he was anything but shy and indeed proved to have a wry sense of humor.*

THE DETAILS: According to some hoax theorists, Neil Armstrong, first man on the Moon, became a recluse and never appeared on TV, refusing all interviews, after the initial celebrations for the Apollo 11 trip. This absence from the media was allegedly due to his guilt for lying to the entire world.



Figure 9.2-1. Neil Armstrong interviewed by Sir Patrick Moore for BBC's The Sky at Night (1970). A transcript is available on Complottilunari.info [http://tiny.cc/m7m6dz].

The truth is quite different. After Apollo 11, he granted countless interviews, such as this one to the BBC (Figure 9.2-1).

In the 1970s Armstrong even did TV advertising campaigns for Chrysler (Figure 9.2-2).



Figure 9.2-2. Neil Armstrong in a TV advert for Chrysler (1979) [http://tiny.cc/qml8dz].

In 1983 he was a guest on the TV show hosted by legendary entertainer Bob Hope, who was Armstrong's personal friend. They had toured together the American military bases in Vietnam in December 1969. In this TV appearance, Armstrong chatted and joked with Bob Hope (Figures 9.2-3 and 9.2-4).



Figure 9.2-3. Neil Armstrong on TV with Bob Hope [http://tiny.cc/i7l8dz].

He was also a guest on TV programs all over the world. Figure 9.2-5 shows him on Italian national channel RAI in 1984. In 1999 he and Buzz Aldrin were even guests on the Italian *Festival di Sanremo* song contest.

However, it is true that Armstrong was famous for being a man of very few words. Apollo astronaut Gene Cernan describes him as follows in his autobiography, *The Last Man on the Moon:*

> *This fellow was a year ahead of our class, and so modest that you would never know he had flown*



Figure 9.2-4. A few stills of Neil Armstrong with Bob Hope during their tour visiting American troops in 1969.



Figure 9.2-5. Neil Armstrong interviewed by Italian national network RAI (1984).

seventy-eight missions in Panther jets off the aircraft carrier Essex and won three air medals. His name was Neil Armstrong. Years later, when Neil was a top test pilot for the experimental X-15 rocket plane at Edwards Air Force Base, Smitty dropped by for a visit and soon found himself beneath the house with the quiet aviator, wrapping pipes with insulation tape. Smitty, by then an aeronautical engineer, was naturally curious about the plane, which was the hottest thing in American skies, and asked, "So, Neil, you're flying the X-15 now?" Neil kept wrapping the pipes and said, "Yup." End of conversation. Neil was not one to worry about impressing people with mere words, content to let his work speak for him. In fact, he was so quiet that when he made his historic first step onto the Moon and said, "That's one small step for man, one giant leap for mankind," those of us who knew him were not surprised that he had come up with such a memorable phrase. The real surprise was that he said anything at all.

It is also true that in later years Armstrong chose his media appearances very carefully and protected his own image against anyone who tried to profit from his lunar endeavor.

For example, in 1994 he sued Hallmark Cards for using his name and voice without permission for a Christmas decoration. Proceeds from the settlement, less legal feeds and costs, were donated to Purdue University, Armstrong's alma mater.

In 2005 Armstrong's barber auctioned off the astronaut's hair clippings, which were bought by a collector for 3,000 dollars. Armstrong threatened legal action and the barber donated the proceeds of the auction to a charity.



Figure 9.2-6. Armstrong's interview with 60 minutes *(CBS, 2005). A partial transcript is available on Complottilunari.info [http://tiny.cc/0am8dz].*

One of Armstrong's few personal interviews was granted in 2005 to CBS's *60 Minutes* (Figure 9.2-6) when his biography, curated by historian James Hansen and entitled *First Man: The Life of Neil A. Armstrong*, was published.



Figure 9.2-7. Neil Armstrong is a guest of the Buffini & Company's MasterMind Summit (2002) [http://tiny.cc/1hm8dz].

Another example of his public appearances is this very



[http://tiny.cc/unm8dz]



[http://tiny.cc/vrm8dz]



[http://tiny.cc/jwm8dz]

Figure 9.2-8. The trailers of the three seasons of First Flights with Neil Armstrong*, a series of documentaries on the history of aviation.*

humorous and at the same time profound video from 2002 (Figure 9.2-7).

Armstrong nevertheless remained an extremely modest and reserved man who preferred to talk about technical matters rather than his personal feelings. He was part of the public inquiry boards for the Apollo 13 accident in 1970 and for the *Challenger* disaster in 1986. These roles placed him once again in the public spotlight at two dramatic times of the United States' space program.

He also hosted the documentary series *First Flights with Neil Armstrong* in 1991 (Figure 9.2-8), in which he explored the history of aviation by interviewing the people who made that history and flew the most extraordinary aircraft. He was also involved in the PBS documentary *Kitty Hawk: The Wright Brothers' Journey of Invention* (2003), in which he lent his voice to Orville Wright. In 2010 he again voiced a character, this time for the animated movie *Quantum Quest: A Cassini Space Odyssey* together with James Earl Jones, Samuel L. Jackson, Chris Pine, William Shatner and many other famous actors.

More recently, he granted extensive technical interviews to the curators of the *Apollo Lunar Surface Journal* and appeared in the documentary *When We Left Earth* (2008).



Figure 9.2-9. Neil Armstrong pays tribute to the crew of Apollo 12 in 2009. Credit: David Meerman Scott, ApolloArtifacts.com [http://tiny.cc/t0m8dz].

On a lighter note, in 2009 he celebrated the fortieth anniversary of the first Moon landing by joining Aldrin and Collins at the *John H. Glenn Lecture*, an annual conference held at the National Air and Space Museum in Washington, D.C., and attended the gala for the fortieth anniversary of Apollo 12 at the Kennedy Space Center, where he demonstrated a talent for self-effacing humor.

In 2010 he also spoke publicly quite vehemently against the plans of the Obama administration to restructure NASA.[1]

1 *Neil Armstrong blasts Obama's 'devastating' Nasa cuts*, by Jacqui Goddard, *Times Online*, April 14, 2010.

These don't seem to be the choices of someone who is shunning publicity out of guilt.

Moreover, Armstrong wasn't at all impossible to reach: for example, in April 2011 some news reports claimed that he had been a follower of Indian guru Sai Baba, who had just died. So I contacted James Hansen, Armstrong's biographer, to clarify the matter.

Within a day, I received a personal e-mail from Neil Armstrong himself.

In late April 2012, a few months before he died, he granted Alex Malley of CPA Australia a long interview (Figure 9.2-11) which was probably the last of his career and in which he told many details of his professional history and of his world view.

Here's another indication that the alleged reclusiveness and humorlessness of Neil Armstrong are journalistic myths: a photograph taken in 1966 (Figure 9.2-12), when Armstrong was part of the prime crew of Gemini 8 together with David Scott, while Pete Conrad and Dick Gordon formed the backup crew.



From [redacted].com>

Subject **Your inquiry** 28.04.11, 23:16

To paolo.attivissimo@gmail.com

Cc James Hansen <[redacted].edu>, Eric Jones <[redacted].com>

Dear M?r/. Attivissimo,

Thank you for your inquiry.

I do not know the name Sai Baba have not communicated in any way with any of his associates or followers.

I am not surprised, however, as many religious organizations have claimed me as a member.

Best wishes,

Neil Armstrong

Figure 9.2-10. The e-mail Neil Armstrong sent me in April 2011.



Figure 9.2-11. Neil Armstrong interviewed by Alex Malley (2012).



Figure 9.2-12. Top left, Dick Gordon; top right, Pete Conrad; bottom left, Dave Scott; bottom right, Neil Armstrong.

9.3 How come NASA refuses to deal with the hoax allegations?

IN A NUTSHELL: *It doesn't refuse. NASA has published various rebuttals to the allegations since at least 1977. But the agency has stated that it has no plans to produce any more because it doesn't want to dignify a set of claims that the science community has long dismissed as ridiculous. NASA prefers to work on more positive enterprises and leave to others the task of answering the individual allegations of fakery.*

THE DETAILS: Some doubters find it suspicious that NASA won't simply answer the hoax theorists' questions once and for all and debate them. It's as if it had something to hide, they argue.

In actual fact, NASA has already published quite detailed rebuttals. After the Fox TV program *Did We Land on the Moon?* was broadcast in 2001, the space agency added several pages of debunking material, based on what it had already released in 1977*:*

- *Did U.S. Astronauts Really Land on the Moon?*, in *NASA Facts*, 1977, republished on April 14, 2001;
- *The Great Moon Hoax*, Nasa.gov, February 23, 2001;
- *The Moon Landing Hoax*, Nasa.gov, March 30, 2001;
- *Did We Really Land on the Moon? Suggestions for Science Teachers*, Nasa.gov, March 4, 2001.

However, there's a limit to how much effort NASA intends to spend in responding to conspiracy theorists. In 2002, in response to the Fox TV program, which had rekindled the "moon hoax" debate, NASA allocated 15,000 dollars and asked aerospace engineer and spaceflight historian James Oberg to write a book specifically on the matter, aimed mainly at teachers and students.

The project was canceled shortly after, following media criticism that it was a waste of taxpayers' money and gave dignity to ridiculous claims. NASA Administrator Sean O'Keefe stated in November 2002 that *"The issue of trying to do a targeted response to this is just lending credibility to something that is, on its face, asinine."* Oberg announced that he intended to continue the project with funding from a different source, but so far no formal debunking publication of his has emerged.

Since then, the widespread availability of the Internet has allowed many enthusiasts and experts to reply to the hoax theories directly on their own websites, and NASA has redirected doubters to these debunkers. The *References* section of this book lists some of the most popular

debunking sites in various languages.

Accordingly, any further direct response by NASA has become essentially unnecessary. The ultimate rebuttal is NASA's overwhelmingly vast library of publicly available documents that provide all the details of the reality of the Moon landings.

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(Reissued)

DID U.S. ASTRONAUTS
REALLY LAND ON THE MOON?

Yes. Astronauts did land on the Moon.

Beginning with the Apollo 11 lunar landing on July 20, 1969, a total of 12 astronauts explored the Moon's surface on foot and traveling in the lunar rover vehicle.

On Apollo missions 11, 12, (Apollo 13 was aborted, but returned to Earth safely), 14, 15, 16 and 17, the commanders and lunar module pilots conducted a series of experiments, photographed their lunar surroundings and returned to Earth 382 kilograms (843 pounds) of lunar surface materials consisting of more than 2,000 separate samples.

From time to time we are asked the question above as a result of at least one book and recurring articles in various publications based either on its content or individuals' expressions of their opinions.

Apart from the fact that millions of people saw the Apollo series on television and heard them on radio in real time, perhaps the lunar material is as irrefutable proof as any that the Moon missions were not "faked." The rocks and particles, still under study by scientists worldwide, were clearly formed in an atmosphere lacking oxygen and water and they show major chemical differences from any previously known Earth rocks. This material could not have been collected, or even manufactured on Earth, and clearly comes from an entirely different world.

Even if NASA had set out to "fake" the Apollo or any of its other programs, there is no possibility it could have done so. Since its inception in 1958, NASA has operated an "open" program, i.e.: all activities have been covered in depth by the news media. For example, during Apollo 11, over 3,500 media representatives from all over the world were at Kennedy Space Center, Florida, for the liftoff. Most of these press, television and radio reporters shifted immediately after launch to Johnson Space Center, Texas, to follow the operational phases through splashdown in the Pacific Ocean and recovery by an aircraft carrier with the U.S. President aboard. Before undertaking the Apollo program, NASA had to justify it to the President and Congress before funds were appropriated. The Apollo series cost approximately $25 billion.

A number of specific queries have been received regarding the book, "We Never Went To The Moon," in which the author claims the Defense Intelligence Agency (DIA) set up a secret organization

- more -

Figure 9.3-1. The front page of NASA Facts *dated 14 February 2001, currently no longer online but archived at Braeunig.us.*

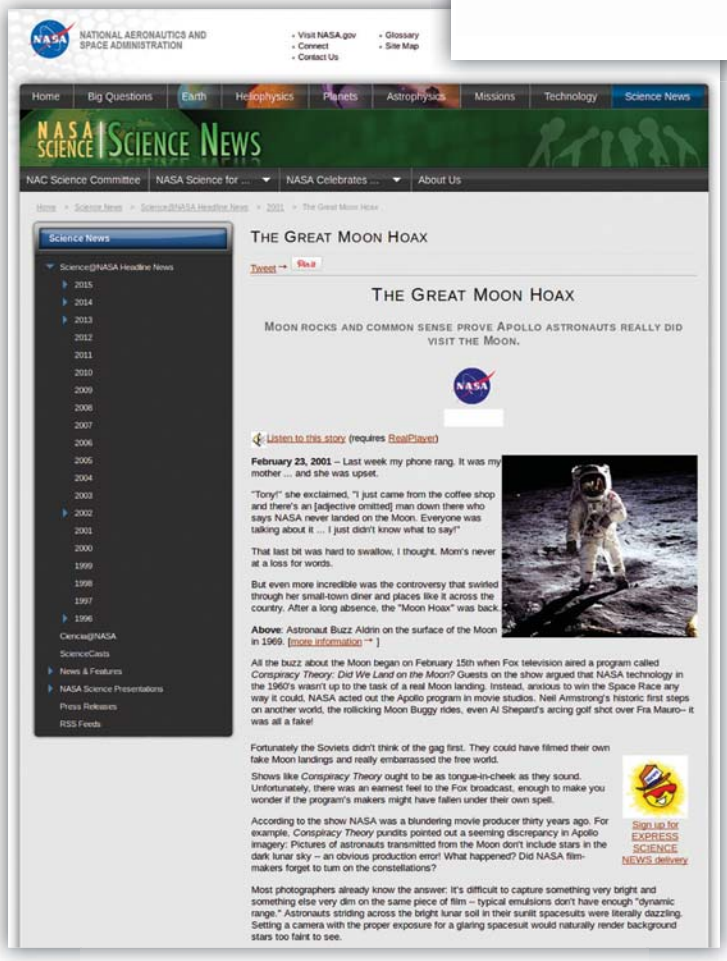


Figure 9.3-2. NASA's rebuttal, published at Science.nasa.gov in 2001.

9.4 How come the lunar astronauts won't face the doubters?

IN A NUTSHELL: *On the contrary, many astronauts have answered the doubters directly, have taken part in TV debates and have granted interviews to hoax believers, even swearing on the Bible in front of the conspiracy theorists' cameras.*



Figure 9.4-1. Top to bottom: lunar astronauts Edgar Mitchell, Gene Cernan and Alan Bean swear on the Bible that they walked on the Moon, as requested by hoax theorist Bart Sibrel. Stills from Sibrel's Astronauts Gone Wild *(2004).*

THE DETAILS: A recurring complaint among Moon hoax proponents is that the Apollo astronauts refuse to debate them and don't answer their questions. This, they say, suggests guilt.

Actually, the astronauts who went to the Moon have engaged the hoax theorists on several occasions. For example, in 2001 John Young (who flew around the Moon with Apollo 10 and landed on it with Apollo 16) went on NBC's *Today Show* to respond to the conspiracy allegations made by Bill Kaysing. He also asked one very pointed question: *"If it was a hoax, why did we do it more than once?".* A full transcript of the program is available at Globalsecurity.org.

Some moonwalkers have actually agreed to be interviewed at length by hoax proponents. Gene Cernan (Apollo 10, Apollo 17), Alan Bean (Apollo 12) and Edgar Mitchell (Apollo 14) even accepted the challenge to swear on the Bible, on video, to comply with Bart Sibrel's insistent demands (Figure 9.4-1).

Others have preferred to reply to these demands with a punch, as in the case of Buzz Aldrin after Sibrel accused him of being *"a coward and a liar"*, or with a knee to the butt, as delivered by Edgar Mitchell again to Sibrel at the end of the interview in which he had sworn on the Bible. Both episodes are documented in Sibrel's video *Astronauts Gone Wild* (2004).

Usually, however, lunar astronauts dismiss the hoax allegations with a few poignant words, such as those chosen by Gene Cernan for the David Sington documentary *In the Shadow of the Moon* (2007):

> *I was there, I made the footprints on the moon, and no one can take that away from me.*

9.5 How come NASA's Apollo documents aren't available?

IN A NUTSHELL: *They are. NASA has always provided access to copies of its technical documents, photographs and film footage for anyone willing to file a formal request and pay for duplication and postage. Now that documents can be distributed at no cost via the Internet, an immense amount of NASA data is available with just a few mouse clicks.*

THE DETAILS: Bill Kaysing, on page 7 of his book *We Never Went to the Moon*, asks this question:

> *Why is it that NASA's Apollo records are not classified, but are also not available to the general public?*

This criticism was perhaps excusable when Kaysing wrote the first edition of his book, in 1974, but today NASA's Apollo documents are easily available on the Internet: tens of thousands of pages of manuals, technical diagrams, reports, and all the photographs of all the Apollo flights. A partial list of these archives is in the *References* section at the end of this book.

Kaysing's claim, however, was factually incorrect even when it was first made: even then, NASA already provided all public records to anyone who requested them and paid the duplication and postage fees. Such requests, however, were rather rare, since just one of the manuals of the Lunar Module, the *Apollo Operations Handbook – Lunar Module, LM 10 and Subsequent*, has over 1700 pages, so duplication costs were high.

Some documents were kept confidential for a few years because they discussed military technologies (such as the ones used in the Apollo 11 lunar camera) or technologies that could be used for military purposes by potential enemies, but even these were soon declassified.

For example, even the documentation related to a truly state-of-the-art item like the Apollo guidance and navigation computer was declassified and made available to the public already in 1973, just four years after the first Moon landing and less than one year after the end of the lunar missions (Figure 9.5-1).


APOLLO
GUIDANCE AND NAVIGATION
R-410
GENERAL DESIGN CHARACTERISTICS OF THE APOLLO GUIDANCE COMPUTER
by
Eldon C. Hall
May 1963
INSTRUMENTATION LABORATORY
CAMBRIDGE 39, MASSACHUSETTS

Figure 9.5-1. The cover of the design report on the Apollo navigation computer. Note the stamps indicating release to the public in 1973.

9.6 How is it possible that the Saturn V blueprints have been lost?

IN A NUTSHELL: *They haven't. They're preserved on microfilm at the Marshall Space Flight Center and on paper at Rocketdyne and in US federal archives. The F-1 engines of the giant rocket are being studied in detail and used as engineering templates for the next generation of spacecraft. Three whole Saturn V rockets are on public display, available to anyone who cares to examine them.*

THE DETAILS: John Lewis, in his 1996 book *Mining the Sky*, reported that he had tried in vain to obtain the blueprints of the Saturn V rocket:

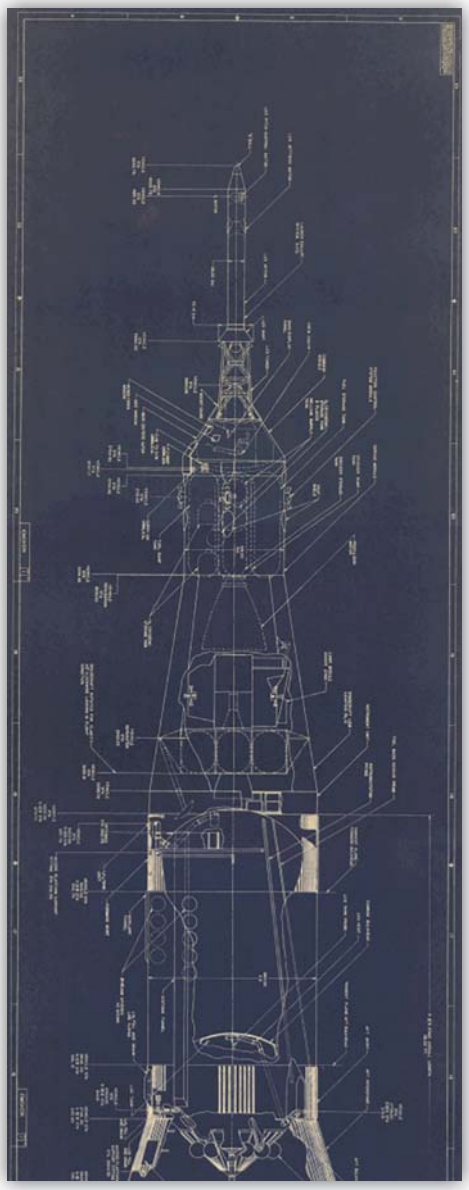


Figure 9.6-1. A detail from one of the allegedly lost schematics of the Saturn V. Credit: Up-ship.com.

> *My attempts to find them several years ago met with no success: the plans have evidently been 'lost'. The fleet has been destroyed. The plans are gone.*

James Collier made a similar claim in his 1997 article *Investigator Challenging NASA* (published originally by *Media Bypass* magazine):

> *I asked for blueprints detailing the scientific thought behind its design.* [...] *Grumman told me that all the paperwork was destroyed. I was stunned. The LM historical paperwork was destroyed!? Why!? They had no answers.*

Some hoax theorists have built on these reports to claim that the blueprints were destroyed to hide the (entirely hypothetical) fact that the Saturn V actually didn't work and couldn't reach the Moon as NASA instead claimed.

However, in 2000 NASA clarified[2] that the blueprints still exist as microfilm at the Marshall Space Flight Center in Huntsville, Alabama. Moreover, the Federal Archives in East Point, Georgia, store approximately 82 cubic meters (2,900 cubic feet) of Saturn documents and Rocketdyne (the manufacturer of the main engines of all three Saturn V stages) has preserved dozens of volumes of Saturn-related information as part of its knowledge retention program.

Moreover, the fleet has not been *"destroyed"*. There are three full, original Saturn V rockets on display and freely accessible to the public:

2 *Saturn 5 Blueprints Safely in Storage*, Space.com, March 13, 2000.

- one at the Kennedy Space Center in Florida;
- one at the Johnson Space Center in Houston, Texas;
- and one at the U.S. Space & Rocket Center in Huntsville, Alabama (Figure 9.6-2).

There is also a complete first stage of a Saturn V at the Infinity Science Center in Mississippi, and a third stage, converted as a spare for the Skylab space station, is at the National Air and Space Museum in Washington. D.C.

The United States and the United Kingdom are also home to *twelve* original Apollo Command Modules and there are three spare Lunar Modules at the National Air and Space Museum in Washington, at the Kennedy Space Center, and at the Cradle of Aviation Museum in Long Island, New York (which houses the LM built for the canceled Apollo 18 mission).

Therefore, anyone who wished to study in extreme detail the technologies used to go to the Moon could do so by examining these spacecraft, the spacesuits and all the other Apollo hardware stored in museums.

In 2013, a team of engineers at the Marshall Space Flight Center in Huntsville, Alabama, actually took to pieces one of the original F-1 engines of the first stage of the Saturn V rocket and test-fired its gas generator, the component that powers the engine's turbopump, which had to inject almost three tons of propellant per second into the thrust chamber. In other words, the fact that these engines really work as advertised is not just a decades-old claim: it has actually been put to the test.



Figure 9.6-2. An original Saturn V on display at the U.S. Space & Rocket Center in Huntsville, Alabama. Credit: Spacecamp.com.

However, it's very important to avoid the mistake of thinking that if the detailed blueprints of the Saturn V and of the Apollo spacecraft still exist, then it should be trivial to build them again and fly them to go back to the Moon. But the necessary know-how, the unwritten skills of the countless workers who painstakingly built by hand each component of these incredibly complex machines, have been lost to time. The people who knew how to perform these delicate manual procedures have aged or died.

Building a 1960s Saturn V would also entail rebuilding from scratch the entire manufacturing pipeline, i.e., the machines that manufacture the components of the machines that used to build the Saturns. Then it would be necessary to rediscover and recreate the testing and quality control equipment and procedures that were used to flight-quality each and every component. The manufacturing,



Figure 9.6-3. This video explains why it would be impractical to build from scratch the giant F-1 engines of the Saturn V rocket [http://tiny.cc/dnn8dz].

inspection, and testing methods we use today are radically different from the ones used in the Apollo era.

Accordingly, remaking a Saturn V would be enormously expensive and inefficient. It would probably be cheaper to design a new rocket from scratch.

9.7 Why is there no delay in the Apollo communications?

IN A NUTSHELL: *Because it's often edited out by documentary makers. To keep the narrative flowing, they often summarize or edit footage. That's why sometimes in documentaries there's no speed-of-light delay in Apollo's Earth-Moon communications. But the delay is there in the unabridged reference recordings and transcripts published by NASA.*

THE DETAILS: In some clips of the footage of the Moon landings, the astronauts appear to answer the radio messages from Earth too quickly. Radio waves, traveling at the speed of light, take about a second and a quarter to cross the gap between the Earth and the Moon, so there should be at least an equivalent pause between the words uttered in Mission Control in Houston and the replies from the astronauts on the Moon. If there's no delay, the radio transmissions must have been fake, argue some conspiracy theorists.

A less conspiratorial explanation is that the footage has been edited for conciseness or pacing with respect to the original recordings. With very few exceptions, documentaries tend to omit unnecessary dialogue and use mismatched images to achieve a more dramatic and interesting narration by focusing on key moments. There's no real intent to deceive, but the end result is that many documentaries are not as faithful as one might expect. The extent to which even prize-winning films, such as *For All Mankind*, present inaccurately and misleadingly images and sounds of the Apollo missions is detailed by spaceflight historian James Oberg's article *Apollo 11 TV Documentary Misrepresentations* (*Wall Street Journal*, 1994).

For example, the Apollo 11 lunar landing is often portrayed so that it seems that the very first words spoken on the Moon were *"Tranquility Base here, the Eagle has landed"*. Actually, if you go to the original recordings and transcripts (available at the *Apollo Lunar Surface Journal* website), it turns out that those famous words were preceded by a substantial chunk of technical reporting.

Here's the unabridged transcript, starting from the very first contact with the lunar surface (Figure 9.7-1):

> *102:45:40 Aldrin: Contact Light.*

Aldrin is telling Mission Control that the Lunar Contact warning light has turned on: this means that at least one of the 173-centimeter (68-inch) probes under the

footpads of the Lunar Module has touched the ground. Technically, *these* are the first words spoken on the Moon.

Once the LM has settled on the surface, the series of technical status reports continues, as the spacecraft is prepared for its stay on the Moon:

> *102:45:43 Armstrong: Shutdown.*
>
> *102:45:44 Aldrin: Okay. Engine Stop.*
>
> *102:45:45 Aldrin: ACA out of Detent.*
>
> *102:45:46 Armstrong: Out of Detent. Auto.*
>
> *102:45:47 Aldrin: Mode Control, both Auto. Descent Engine Command Override, Off. Engine Arm, Off. 413 is in.*

Only at this point does Mission Control speak out: Charlie Duke, future Apollo 16 astronaut, is working as Capcom for Apollo 11. He is one of the few people who talk directly to the crew in space:

> *102:45:57 Duke: We copy you down, Eagle.*
>
> *102:45:58 Armstrong: Engine arm is off.* [pause] *Houston, Tranquility Base here. The Eagle has landed.*

It's quite obvious that these status reports are of no interest to the average viewer: that's why they often get cut in documentaries.



Figure 9.7-1. Audio and onboard footage of the Apollo 11 Moon landing. Contact is announced at 14:30 [http://tiny.cc/vtn8dz].

Another frequent example of a cut for narrative purposes occurs seconds later: Charlie Duke, momentarily tongue-tied by the excitement of the event, mispronounces the new name of the Lunar Module, i.e., *Tranquility Base*.

He starts to say *"Roger, Twan...",* then pauses and corrects himself: *"...Tranquility. We copy you on the ground. You got a bunch of guys about to turn blue. We're breathing again. Thanks a lot."* In most documentaries this flub is edited out.

Even the famous phrase *"One small step for [a] man,*



Figure 9.7-2. Photos, live TV and 16 mm footage of the beginning of the Apollo 11 moonwalk. Armstrong's famous words are at 3:30 [http://tiny.cc/z1n8dz].

one giant leap for mankind" is often presented in the wrong context for the sake of brevity: it's usually heard as we see Neil Armstrong jump down the ladder of the LM. But actually, in the original video recording Armstrong jumps down and lands on the LM footpad, without touching the ground, describes his surroundings, hops up the ladder again (to test that he will be able to get back up at the end of the moonwalk), jumps down again, and only then does he cautiously place his left foot on the surface of the Moon and utter the historic words (Figure 9.7-2).

Conspiracy theorists persistently make the mistake of considering documentaries to be equivalent to official records. They are not; the only true reference material is constituted by the original raw data and footage.

There's also another even less dramatic explanation for the apparently missing delays: sometimes the astronauts on the Moon answered the first part of a message from Houston and then the voice from Earth continued talking, creating what sounds like an excessively short gap. The astronauts also sometimes began speaking of their own initiative instead of responding to a communication from Earth and then Mission Control started speaking, giving the impression that the astronauts were answering and were doing so too soon.

Besides, had the Earth-Moon conversation been faked, why would the hypothetical fakers have been so stupid as to forget to include the radio delay?

9.8 How come the Moon rock donated to Holland is fake?

IN A NUTSHELL: *Because it's not a NASA Moon rock. Everything points to a mistake or to a hoax orchestrated by two Dutch artists in 2006. NASA has never authenticated the "rock" (there are no documents tracing its origins), it's far too big to be a donated lunar sample, and its background story is nonsensical. It was reportedly donated privately in 1969 to a retired prime minister instead of being given, as was customary, to a representative of the then-current Dutch government; it wasn't put on public display as a Moon rock would have deserved; and real donated Moon rocks were encapsulated in transparent plastic, while this one is not.*

THE DETAILS:[3] In August 2009, several media outlets began reporting that the curators of the Dutch national museum in Amsterdam, the Rijksmuseum, had discovered that an exhibit that had been presented for years as an Apollo 11 Moon rock was actually a chunk of petrified wood (Figure 9.8-1).

3 *I am indebted to Diego Cuoghi for sharing his research into many of the details of this story.*

The reports stated that the alleged Moon rock had been donated on October 9, 1969 by J. W. Middendorf II, who was the US ambassador to the Netherlands at the time, to a former Dutch prime minister, Willem Drees, during the world tour of the Apollo 11 astronauts following their historic mission. When Drees died, in 1988, the item was reportedly put on display in the museum.

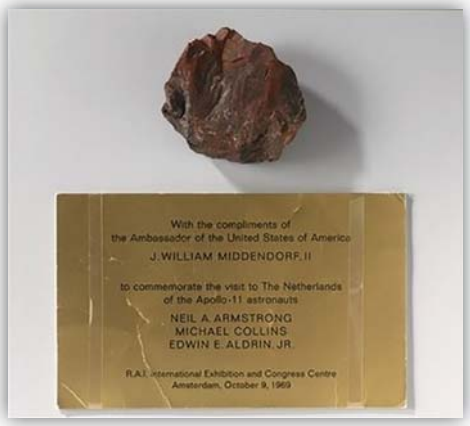


Figure 9.8-1. The fake "Moon rock" and its descriptive card. Credit: Associated Press.

However, in 2006 Arno Wielders, a physicist and aerospace entrepreneur, saw it and warned the museum that it was highly unlikely that NASA had donated such a priceless Moon rock just three months after returning from the Moon and before any further samples were brought back by later Apollo flights. Moreover, the lunar samples donated to other countries were tiny fragments, whereas this "Moon rock" measured 55 by 20 millimeters (2.2 by 0.8 inches).

A phone call to NASA's lunar rock sample management office confirmed these doubts: the curator stated that the item could not possibly be a Moon rock.

The investigation conducted in 2009 by Xandra Van Gelder, chief editor of the museum's *Oog* magazine, confirmed that the exhibit was a fake. Van Gelder reported that NASA hadn't authenticated the specific item but had merely stated that it was likely that the Netherlands had received a Moon rock, since the US had donated small samples to over 100 countries in the early 1970s.

Van Gelder also noted that the history of the item was suspicious. Real samples would be donated by the US government to the people of a country through a representative of the then-current government, not to a former prime minister who in 1969 had been out of office for eleven years. The US ambassador explained that he had received the exhibit from the US State Department, but he could not recall the details of the matter.

In addition to its inconsistent and implausible history, the fakery, if intended, wasn't particularly subtle. The reddish color of the item was completely different from the usual color of lunar samples. Petrologist Wim van Westrenen, of the Amsterdam Free University, reported that he was immediately aware that something was wrong. Spectroscopic and microscopic inspection of a fragment taken from the item found quartz and cell-like structures typical of petrified wood.

Further anomalies become evident if the item is compared with a real sample donated to the Netherlands and stored at the Boerhaave museum (Figure 9.8-2).



Figure 9.8-2. At the top, encapsulated in clear plastic, a genuine sample of Moon rock donated to the Netherlands by the US. Credit: Museumboerhaave.nl.

The real Dutch sample is encapsulated in plastic and accompanied by a national flag and by plaques that clearly identify it as fragments of Moon rocks retrieved by Apollo 11 and *"presented to the people of the Kingdom of the Netherlands by Richard Nixon, President of the United States of America"*. Specifically, the plaque states that *"this flag of your nation was carried to the Moon and back by Apollo 11, and this fragment of the Moon's surface was brought to Earth by the crew of that first manned lunar landing."*

The alleged "Moon rock" is not encapsulated or mounted in any way and is simply accompanied by a gold-colored card. This card doesn't even say it's a lunar sample and spells *center* with an incongruous British spelling (*centre*) and hyphenates the name of the mission (*"Apollo-11"*).

Another questionable issue is the fact that such a rare and important item (there are only 382 kilograms (842 pounds) of Apollo moon rocks in the entire world) surfaced only during an *"art exhibition"* organized in 2006 by Rotterdam artists Liesbeth Bik and Jos van der Pol and not during a science-oriented event. The exhibition was rather tongue-in-cheek, since it asked visitors what they thought of the museum's plans to open an exhibition center on the Moon.

However, it is true that on October 9, 1969 the Apollo 11 astronauts actually were in Amsterdam on an official visit.



Figure 9.8-3. The "Moon rock" as shown in the Rijksmuseum catalog (where it was classified as fake).

For all these reasons, the "Moon rock" is now cataloged by the Rijksmuseum as item number NG-1991-4-25 and described as a *"piece of black and red petrified wood"* and classified unquestionably as *"fake"*. The words *"Moon rock retrieved by the Apollo 11 crew"* are described as merely the title of the artwork.

All this suggests an art exhibit that created a fictional backstory which was misinterpreted or deliberately presented as factual. This would explain the fact that the artists who found the "rock" in the storage section of the museum reported in 2007 that *"in a drawer they saw a very small rock with a note with it. On that note it said that this stone came from the moon."* Yet the photographs of the note show that it doesn't say that the stone is a lunar specimen.

Moreover, the book *Museums: A Visual Anthropology* by Mary Bouquet describes NG-1991-4-25 as follows on page 58:

> Bikvanderpol's *Fly Me to the Moon* was a meditation on the social life of a piece of moonrock donated to the national collection by former Dutch premier Willem Drees's family after his death (Bikvanderpol 2006). Although NG-1991-4-25 was subsequently unmasked as a piece of fossilized wood, this only augments its heritage interest.



Figure 9.8-4. Bottom left: the alleged Moon rock in a photograph described as "Drawer with collection of Drees objects" in the book NG-1991-4-25. Scan from my personal book collection.

Bouquet's book, on page 210, also references the item with the words *"Bikvanderpol (2006), NG-1991-4-25 Fly Me to the Moon, New York: Sternberg"*. This appears to be a reference to a book by the same name written by Liesbeth Bik and Jos van der Pol and available for purchase through Google Books and online stores with ISBN 1933128208.

The book, which I purchased in 2019, includes a few photographs of the "Moon rock": two are shown in Figures 9.8-4 and 9.8-5. The text of the book seems to suggest that a misunderstanding is more likely than an intentional prank.

In any case, it is unquestionable that the item was not formally authenticated by NASA and that anyone arguing that this is evidence of faking the trips to the Moon would have to explain why the perpetrators of a conspiracy on which the worldwide standing of the US depended would be so dumb as to manufacture such a crude and easily detectable fake.



Figure 9.8-5. The alleged Moon rock in a photograph described as "Card belonging to moonrock" in the book NG-1991-4-25. Scanned from my personal book collection. Credit: Rijksmuseum Amsterdam.

9.9 Was astronaut Grissom killed to keep him quiet?

IN A NUTSHELL: *No. The accident in which Grissom died actually* revealed *the problems with the Apollo spacecraft in a tragic way that nobody could ignore.*



Figure 9.9-1. Scott Grissom in the documentary Did We Land on the Moon? *(2001).*

THE DETAILS: In the 2001 Fox TV program *Did We Land on the Moon?*, Scott Grissom (Figure 9.9-1), son of astronaut Gus Grissom who died with Ed White and Roger Chaffee in the fire of their Apollo 1 Command Module during a ground test on January 27, 1967, stated that the spacecraft *"was intentionally sabotaged".*

Some Moon hoax proponents claim that Grissom was killed because he was an outspoken critic of the Apollo program and was about to announce that the spacecraft would never be able to get to the Moon.

In other words, allegedly Gus Grissom was going to disclose that the Apollo spacecraft was dangerously unsafe and unreliable and so someone decided to shut him up by making him die in an onboard fire that disclosed to everyone that the Apollo spacecraft was dangerously unsafe and unreliable. A flawless plan.

Scott Grissom's accusations are not backed by any hard evidence. The Fox TV program says that *"the cause of the fire is still a mystery and the capsule remains locked away at a military base",* but this statement is twice incorrect and misleading.

First of all, the *specific* cause of the fire, i.e., the exact component that triggered it, is not known, but the *general* causes of the blase are not a mystery at all: seconds before the first report of fire by the crew, telemetry tapes recorded a short-circuit in the spacecraft cabin, which was built with materials that became highly flammable in a high-pressure (1.13 atm, 16.7 psi), pure-oxygen environment such as the one used for the specific test that was being run on that fatal day. In these conditions, the slightest spark, for example due to static electricity or faulty wiring, could trigger a raging blaze, and it did.



Figure 9.9-2. The Apollo 1 hatch opening shows the charred interior of the spacecraft.

The crew was trapped in the spacecraft by the complicated double hatch, which opened inward and therefore was pressed shut by the sudden internal pressure build-up caused by the heat. Grissom, White and Chaffee died within seconds due to inhalation of toxic gases from the fire.

The tragedy forced NASA and its contractors to

review all their procedures and rethink the redesign of all the Apollo spacecraft that was already in progress, focusing on the need to minimize the risk of fire.

In the course of twenty-one frantic months, all flammable materials were replaced by self-extinguishing ones, the nylon spacesuits were replaced with fire- and heat-resistant models, a hatch that could open outward in less than ten seconds was introduced and the onboard atmosphere was changed to 60% oxygen and 40% nitrogen at sea level pressure during liftoff and 0.3 atm (5 psi) of pure oxygen for the remainder of the flight. Apollo 7 was the first flight to introduce these fixes.

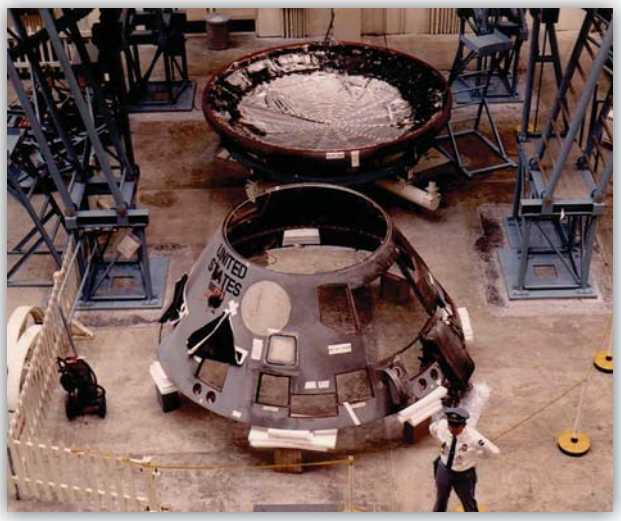


Figure 9.9-3. Part of the remains of the Apollo 1 spacecraft. Source: Chariots for Apollo.

Secondly, the Apollo 1 capsule is not *"locked away at a military base"*, as if to suggest some secret that has to be kept under wraps: records show that at the end of the inquiry into the accident the capsule was taken to NASA's Langley Research Center in Hampton, Virginia, where it remained until 2007. After that date it was placed in an environmentally controlled warehouse at the same center, which is not a military base (NASA is a civilian agency), although there is a military facility nearby.



Figure 9.9-4. The Apollo 1 display opened in January 2017 includes the three layers of the complicated double hatch of the original spacecraft. Source: NASA. Credit: Kim Shiflett.

On 27 January 2017, exactly fifty years after the fatal fire, a memorial display was opened to the public at the Kennedy Space Center Visitor Complex. This display describes the Apollo 1 disaster and the lives of its three astronauts and includes the original hatch of the spacecraft.

The mystery, in other words, is entirely fabricated by Fox TV's sensationalist scriptwriters.

Moreover, the alleged motive makes no sense also because Grissom was far from being a lonely voice in the desert as regards the flaws of the Apollo spacecraft. Indeed, a major redesign of the spacecraft was already in progress and NASA's post-accident report stated openly that *"deficiencies in design, manufacture, installation, rework and quality control existed in the electrical wiring... No design features for fire protection were incorporated... Non-certified equipment items were installed in the Command Module at time of test."*[4]

4 *Report of Apollo 204 Review Board – Findings, Determinations and Recommendations* (1967).

9.10 Was NASA whistleblower Thomas Baron murdered?

IN A NUTSHELL: *He died* after *he testified; not an effective way to silence a witness. Safety inspector Thomas Baron died in a car accident after testifying in writing before Congress and after publishing his criticism of the safety of the Apollo spacecraft.*

THE DETAILS: Thomas Ronald Baron was a safety and quality inspector who worked at the Kennedy Space Center from September 1965 to November 1966. He reported to his superiors many acts of worker negligence, poor workmanship and disregard for safety rules.



Figure 9.10-1. Thomas Baron.

His reports, however, were not based on direct observation, but on second-hand notes from other people, and this caused them to be taken lightly. He submitted some of his remarks to NASA at the end of 1966 in a 55-page report; some of his warnings were heeded, while others were considered groundless. Baron felt disregarded and sidelined and so leaked his criticism directly to the press. This decision led North American Aviation (the manufacturer of the Apollo Command Modules) to fire him in January 1967.

Baron began to draft on his own a more detailed 500-page report. After the Apollo 1 fire, which took the lives of Grissom, White and Chaffee on January 27, 1967, Baron delivered this report to the committees of the US Congress that were investigating the disaster and on April 21, 1967 testified before a subcommittee governed by Congressman Olin Teague.

One week after testifying, Baron and his family were killed when their car was struck by a train at a level crossing. His full-length report was never made public and has since vanished.

If the facts are told in this way, they certainly lend themselves to a conspiracy theory: Baron was killed to silence him and make sure that nobody found out that the Apollo project was in deep trouble or was a sham.

However, this theory clashes with a basic logic flaw: Baron died *after* he had talked to the press, *after* delivering his extended report to Congress, *after* testifying before the commission subcommittee, and *after* the very serious problems in the design of the Apollo command module had become public in the most tragic and inescapable way: with the death of three astronauts. Silencing Baron at this point would have been absolutely useless.

Moreover, while the nature of the accident that killed Baron and his family might seem freakish and suspicious at first glance, if you consider the logistics of coordinating a train to pass at the exact time when Baron's car is passing and making sure Baron can't see it and avoid being struck, it seems an absurdly complicated way to go about eliminating an embarrassing witness.

What happened to the 500-page report is unclear. The transcripts of Baron's testimony (which are publicly available) indicate that the report was discussed and that the Congress committee was reluctant to include it as an official record because its size made it awkward and costly to duplicate and print it, especially if the report included hearsay, which would have been legally inadmissible anyway.

NASA and North American Aviation, the organizations that had most to lose from its publication, never had the opportunity to destroy it, since Baron gave it directly to the Congressmen. It is unknown whether the report was returned to Baron or simply discarded.

Either way, it mattered little whether the report was saved or not: NASA and especially North American Aviation were already in the spotlight for the Apollo 1 disaster and their omissions had already been made public. Baron's report would have made no difference before the coffins of Grissom, Chaffee and White (Figure 9.10-2).



Figure 9.10-2. Gus Grissom's coffin at the Arlington cemetery, escorted by Alan Shepard, John Glenn, Gordon Cooper and John Young. Photo 67-H-141. Scan by Ed Hengeveld.

9.11 Isn't it suspicious that ten astronauts died in freak accidents?

IN A NUTSHELL: *No. Two of the ten astronauts had nothing to do with the Apollo project: the compilers of this death list are cooking the books. Also, being a test pilot of experimental, high-performance aircraft and spacecraft has always been dangerous and deadly. Test pilots died often, in the Fifties and Sixties, outside of the American space program as well, as witnessed by any aviation history book.*

THE DETAILS: The Fox TV program *Did We Land on the Moon?* states that *"Between 1964 and 1967, a total of ten astronauts lost their lives in freak accidents. These deaths accounted for an astonishing 15% of NASA's astronaut corps."*



Figure 9.11-1. From 33:44 onwards, Did We Land on the Moon? *talks about ten allegedly mysterious deaths without naming the people shown.*

Bill Kaysing then adds that *"to keep something that's a lie wrapped up and covered over, you've got to eliminate all the people that can talk about it".* The implication is that these *"freak accidents"* were staged to keep under wraps the secret that the Apollo missions would be faked. Conspiracy theorists, here, are no longer talking about doctored photographs: they're openly making accusations of murder.



Figure 9.11-2. Fox TV fails to identify this man. He's USAF captain Theodore C. Freeman.

The program shows photographs of ten men without bothering to identify them (Figure 9.11-1).

Because of this lazy lack of identification, patient, time-consuming historical research is necessary to find their names and check whether they actually did die in freak accidents and what their involvement in the Apollo program was.

It turns out that *two of them weren't even part of the Apollo program*. Further details on these men are in the chapter *Remembering the fallen*, but here are the key facts.



Figure 9.11-3. USAF major Edward G. Givens, not named by Fox TV.

Figure 9.11-2 shows Theodore Cordy Freeman, USAF captain, aeronautical engineer and experimental aircraft test pilot. He died in 1964, two years before the first test flight of the Apollo spacecraft and three years before the first flight of a Saturn V, in a plane crash caused by a bird strike. He had been selected as an astronaut for the Gemini and Apollo projects but was never assigned to a specific mission.

The man in Figure 9.11-3 is Edward Galen Givens, Jr.: USAF major and test pilot, selected and trained by NASA in 1966 as an astronaut for the *Apollo Applications Program*, a planned series of flights that were intended to follow the first lunar landing. He was on the backup crew of Apollo 7. He died in a car accident in 1967.



Figure 9.11-4. USAF major Robert H. Lawrence, Jr. He is not identified by Fox TV and was not part of the Apollo program.

Robert Henry Lawrence, Jr. (Figure 9.11-4) was a USAF major and test pilot, selected in June 1967 for the *Manned Orbiting Laboratory* project, which intended to place military space stations in Earth orbit to perform reconnaissance of enemy territories. He died on December 8, 1967 in the crash of his F-104 trainer, flown by his student. He was not involved in the Apollo program.



Figure 9.11-5. USMC major Clifton C. William, not identified by Fox TV.

Figure 9.11-5 is a photograph of Clifton Curtis Williams, Jr., major of the Marines and test pilot, chosen for NASA's third group of astronauts in 1963. He was part of the backup crew of Gemini 10 and Apollo 9. He died in 1967 when the T-38 supersonic trainer that he was flying developed a malfunction and crashed.

The man in Figure 9.11-6 is Elliot McKay See, Jr., US Navy engineer and test pilot, selected as an astronaut by NASA in 1962. He also supervised the design and development of spacecraft guidance and navigation systems. He had been chosen to command Gemini 9, but died on February 28, 1966 together with astronaut candidate Charles Bassett when their T-38 jet crashed during a low-visibility instrument-only landing.



Figure 9.11-6. US Navy test pilot Elliot M. See, not identified by Fox TV.

Figure 9.11-7 shows Michael James Adams. He was a USAF major and test pilot, selected as astronaut for the *Manned Orbiting Laboratory* military project. He died on November 15, 1967, when his X-15 experimental hypersonic rocket plane broke up as it was flying at five times the speed of sound. He was not involved in any way with the Apollo project.



Figure 9.11-7. USAF major Michael J. Adams, not identified by Fox TV. He was not part of the Apollo program.

Charles Arthur "Art" Bassett II (Figure 9.11-8) was a USAF captain and test pilot. Member of NASA's third group of astronauts, selected in October 1963. He was assigned to Gemini 9 together with Elliot McKay See, but died with See on February 28, 1966, in the crash of their T-38 trainer.

The last photo shown by Fox TV without identification shows Virgil Ivan "Gus" Grissom, Edward Higgins White, Roger Bruce Chaffee. As already described in the previous chapters of this book, these three astronauts died together in a fire on the launch pad, during a spacecraft systems test, on January 27, 1967.



Figure 9.11-8. USAF captain Charles A. Bassett II, not identified by Fox TV.



Figure 9.11-9. Virgil I. Grissom, Ed H. White and Roger B. Chaffee, not identified by Fox TV.

To sum up the allegedly suspicious deaths:

- two involved military astronauts (Michael James Adams and Robert Henry Lawrence) who had nothing to do with the Apollo project;
- four (Charles Bassett, Elliott See, Theodore Freeman and Clifton Williams) occurred in three accidents with T-38 supersonic training jets (they were test pilots);
- one (Ed Givens) was the result of a car crash;
- and Gus Grissom, Ed White and Roger Chaffee died in the Apollo 1 fire.

Ten deaths over three years was sadly par for the course in the high-risk world of test pilots in those days, as Tom Wolfe's *The Right Stuff* mercilessly recounts, so statistically there's nothing particularly suspicious about these events.

What *is* suspicious, instead, is that the Fox TV list includes two people who were not part of the Apollo project. It's easy to create an atmosphere of mystery if you inflate the number of deaths by 25%.

9.12 Why has Wernher von Braun's name been removed from German schools?

IN A NUTSHELL: *Because of his Nazi past, not because of any suspicion that he might have faked the Moon landings. And his name was removed from just* one *school.*

THE DETAILS: Some conspiracy theorists allege that some German schools that had changed their name to honor Project Apollo's master rocket designer, Wernher von Braun, have since changed it again to remove all mention of his name. This is said to have occurred because the schools discovered that the Moon landings were faked with the German scientist's help. These schools, however, are not identified by the promoters of this theory.



Figure 9.12-1. Wernher von Braun, in civilian dress, next to Nazi officers in Germany, March 1941.

Actually, only *one* German school that was named after von Braun is known to have subsequently changed its name again: a *Gymnasium* (high school) in Friedberg, Bavaria, was named after him in 1979, shortly after his death in 1977.

In 2012 this *Wernher-von-Braun-Gymnasium* was renamed to *Staatliches Gymnasium Friedberg*, but not due to von Braun's involvement with the Apollo program: the name was changed because von Braun had been a military member of the Nazi Party during World War II as a rocket scientist. Before surrendering to US troops in 1945, he had designed rocket weapons such as the V-2 for the German army.[5]

5 *"Tut alles, damit dieser Name verschwindet"*, by Stefan Mayr, *Süddeutsche Zeitung*, 23 March 2012.

9.13 How come Neil Armstrong once spoke of removing "truth's protective layers"?

IN A NUTSHELL: *He was referring to scientific truth, since he was talking to students to encourage them to make new discoveries.*

THE DETAILS: Conspiracy theorist Richard Hoagland noted more than once that Neil Armstrong, during a public speech, mentioned *"truth's protective layers"*.

These words are seen, by him and by many other conspiracy theorists, as a cryptic confession of some secret that involved him. This secret, it is claimed, is clearly tied to his mission to the Moon, Apollo 11.



Figure 9.13-1. Neil Armstrong"s speech at the White House (1994) [http://tiny.cc/r7suez].

Let's gather the facts. The speech being referenced is the one he made at the White House for the twenty-fifth anniversary of the first Moon landing, on July 20, 1994, in front of then president Bill Clinton and vice president Al Gore. Armstrong's Apollo 11 crewmembers, Buzz Aldrin and Michael Collins, were also there (Figure 9.13-1).

Here is a transcript of Armstrong's short speech:

> *Wilbur Wright once noted that the only bird that could talk was the parrot, and he didn't fly very well* [laughter from the audience]*, so I'll be brief. This week America has been recalling the Apollo program and reliving the memories of those times in which so many of us here, the colleagues here in the first rows, were immersed. Our old astrogeology mentor, Gene Shoemaker, even called in one of his comets* [laughter from the audience] *to mark the occasion with spectacular Jovian fireworks* [he is referring to the Shoemaker-Levy 9 comet, which crashed into Jupiter on July 16-22, 1994] *and reminding us one again of the power and consequence of celestial extracurricular activities.*
>
> *Many Americans were part of Apollo, about one or two in each thousand citizens, all across the country. They were asked by their country to do the impossible -- to envisage, to design and to build a method of breaking the bonds of Earth's gravity and then sally forth and visit another heavenly body. The principal elements -- leaving*

> *earth, navigating in space and descending to a planet unencumbered with runways and traffic controls -- would include the major requirements necessary for a spacefaring people.*
>
> *Today a Space Shuttle flies overhead with an international crew. A number of countries have international space programs. During the space age we have increased the knowledge of our universe a thousandfold.*
>
> *Today we have with us a group of students, among America's best. To you we say: we've only completed the beginning. We leave you much that is undone.* ***There are great ideas undiscovered, breakthroughs available to those who can remove one of truth's protective layers.*** *There are places to go beyond belief. Those challenges are yours -- in many fields, not the least of which is space, because there lies human destiny. Thank you.*

This is the context in which Neil Armstrong speaks the words in dispute: he is addressing students, to whom he is passing the torch, inviting them to discover hidden truths just like any scientist does when he or she tries to unmask the secrets of nature, which tends to protect them; he is also asking them to do so in any field, not just in space.

In other words, conspiracy theorists are forcing an interpretation of Armstrong's words to adapt them to their predefined argument.

10 Alternative realities

Sometimes Moon hoax proponents realize that their alleged evidence entails absurdities or contradictions and try to justify them with other allegations. This generates a vast web of accusations that go beyond the details of the Apollo missions and enter the realm of politics and history. If you need to discuss Moon hoax theories, it is advisable to be familiar with these alternative interpretations of reality in order to avoid their pitfalls and spot their fallacies.

The following pages present some of the most popular concepts of these alternative realities: in addition to showing their errors and contradictions, they are revealing examples of the conspiracist mindset.

10.1 Were the Soviets bribed to keep quiet?

IN A NUTSHELL: *No. If so, why would they secretly build the giant N1 Moon rockets? And the silence-for-grain theory doesn't hold up.*

THE DETAILS: When a Moon hoax believer is asked to explain why the Soviets didn't denounce the alleged US fakery, one frequent reply is that the Soviet government was silenced by a bribe it couldn't refuse. Ralph Rene, in *Nasa Mooned America!*, claims that this bribe was a huge amount of grain sold below cost by the United States to Russia in 1972.

However, a little fact-checking of history files shows that there was no secret deal between the two rival countries: on the contrary, the Soviet Union contrived a clever plan to covertly purchase on the free market, through shell companies and in the course of a few weeks, 30% of the US grain crop and even managed to take advantage of the US government's farming export incentives. The press aptly called this scam *The Great Russian Grain Robbery*, as a reference to the then-famous British great train robbery of 1963.

Contrary to Rene's claims, the grain wasn't sold below cost, but the huge purchase triggered a market rush which tripled the price within a year. The Russians even managed to pull a similar trick again in 1975.[1]

It should be noted that US grain sales to Russia were not unusual: smaller negotiated deals had been made even

1 *What Land Crash?* by Marcia Zarley Taylor, AgWeb.com (2007); *Another Soviet Grain Sting*, in *Time*, Nov. 28, 1977.

during President Kennedy's term and West European countries had also been involved.

In other words, Rene is reversing cause and effect in order to make the events fit his preconceptions: the US didn't sell the grain below cost, but rather the Russian purchase made grain prices rise later on.

There's also a bigger picture to be considered: if a discounted sale of grain was really all it took to keep the Russians quiet and convince them to lose face in the space race, then why wasn't this leverage used to obtain other, perhaps more useful results, such as keeping the Russians out of the Vietnam War or ending the nuclear arms race? Instead of solving a contradiction, Rene's justification merely leads to an even bigger absurdity.

This bribery scenario also entails a further increase in the number of participants to the conspiracy and in the consequent risk of someone, sooner or later, spilling the beans: the Russians, too, would have to be in on the fakery and would have to keep the secret flawlessly for decades.

Moreover, if the Russians were paid off to let the US win the race to the Moon, why did they bother to design and build a rival Moon rocket, the giant N1 (Figure 10.1-1), and the lunar landing craft L3, which they would never use?



Figure 10.1-1. A Soviet N1 rocket under construction.



Figure 10.2-1. A cross-section from the Lunar Petrographic Educational Thin Section Set*, which can be requested by any geology faculty.*

10.2 Were the Apollo Moon rocks faked?

IN A NUTSHELL: *No. It would have been technically impossible and it would have been very easy to spot any attempted forgery, especially by comparing them with Russian samples.*

THE DETAILS: Some conspiracy theorists argue that the rock samples returned from the Moon were actually created in a laboratory on Earth so that they would fool even the experts: an easy task, they say, since there were no other Moon rock samples to which they could be compared.

As an alternative, they allege that meteors of lunar origin found on Earth were used and that only trusted geologists were allowed to examine the samples, which were tightly controlled with the excuse that they were rare and valuable.

The facts, however, don't support these claims: every year, approximately 400 samples from the Apollo Moon rocks are given out to the public for scientific and educational purposes. Requesting a sample is a fairly simple procedure.[2]

The *Lunar Sample Disk Kit*, containing Apollo Moon rocks encapsulated in transparent material, is available to any teacher that follows a three-hour certification course.[3]

Many samples of these Moon rocks have been donated to museums in over 100 countries of the world and are on public display (Figures 10.2-2 and 10.2-3).

NASA also allows anyone who has adequate professional credentials to pick up Apollo Moon rock samples, embedded in lucite, for exhibitions or conferences. I personally accompanied Luigi Pizzimenti, an Italian museum curator and Apollo historian, to Houston to collect and carry these samples for two conference tours in 2015-17 in Italy and Switzerland.

Moreover, it is incorrect to claim that no comparisons are possible, because the Soviet probes Luna 16, 20 and 24 returned lunar soil samples to Earth between 1970 and 1976.

2 *Sample Requests for Research*, Nasa.gov; *Goddard Exhibits for Loan - Lunar and Meteorite Sample Request Process*, Nasa.gov.

3 *Lunar and Meteorite Sample Disk Program (K-12)*, Nasa.gov.



Figure 10.2-2. A Moon rock sample returned to Earth by Apollo 17 and on public display at the Museum of Transportation in Luzern, Switzerland. Credit: PA.

The idea to use lunar meteorites found on Earth and pass them off as samples brought back by the Apollo astronauts is shot down by the fact that the Apollo samples have many features that lunar meteorites can't have. One of the most conspicuous is that the surface of the Apollo Moon rocks is pockmarked with minute craters produced by the high-speed impact of micrometeoroids (Figure 10.2-4).

This feature could not be replicated in a laboratory in the 1960s and is not observed in lunar meteorites found on Earth because the heat and friction of their fiery dive through the atmosphere erodes their surface.

The geological characteristics of the Apollo rocks also confirm their nonterrestrial origin: they lack water-bearing minerals and show none of the geologic changes that characterize Earth's rocks.

For example, here's the expert opinion of Steven Dutch, professor of geology at the University of Wisconsin, who examined the Apollo samples personally and replied to the allegations of fakery in his review of the Fox TV *Conspiracy Theory: Did We Go to the Moon?* show (Uwgb.edu, 2001):

> *Water is ubiquitous on earth - it's present in magma, rocks deep in the crust are changed by hot fluids, and rocks near the surface are altered by surface water. Olivine in particular is easily altered. In the second picture* [Figure 10.2-5]*, the olivine is fractured but the fractures are absolutely clean. You simply do not see unaltered olivine on earth.*
>
> *This could not have been faked. These rocks have grains easily visible to the unaided eye, which means they cooled slowly. To have made these materials synthetically would have required keeping the rocks at 1100 C for years, cooling them slowly at thousands of pounds per square inch pressure. It would have taken years to create the apparatus, years more to get the hang of making the materials, and then years more to create the final result. Starting from Sputnik I in 1957, there would not have been enough time to do it. And, you'd have to synthesize several different types of rock in hundred-pound lots.*
>
> *...Why create absolutely water-free rocks? Nobody was expecting that - it would have been much easier to fake rocks with water in them (for one thing, you could use terrestrial rocks) and nobody would have been suspicious. And you'd have to put in exactly the right amounts of radioactive elements and daughter products to get the rocks*



Figure 10.2-3. The Apollo Moon rock sample donated to Italy, on display at the Science and Technology Museum in Milan, Italy. Credit: Gianluca Atti (2015).

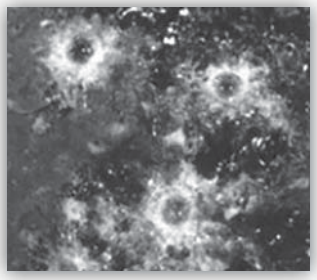


Figure 10.2-4. An enlarged view of the tiny craters produced by micrometeoroids on Moon rocks.

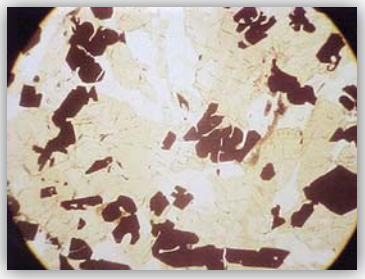


Figure 10.2-5. A cross-section of an Apollo Moon rock photographed by Steven Dutch, University of Wisconsin.

to date radiometrically at 4 billion years old - older than any terrestrial rocks. And you'd have to anticipate the development of new dating methods not in use in 1969 and make sure those elements are present in the correct abundance. And it's not like adding carrots to a stew, either. To mimic the results of potassium-argon dating, you'd have to add inert argon gas and trap it just in the potassium-bearing minerals, and in exact proportion to the amount of potassium.

10.3 Did Stanley Kubrick shoot the fake footage?

IN A NUTSHELL: *No. He wouldn't have had the time. And if he had, he would have done a better job.*

THE DETAILS: The name of movie director Stanley Kubrick, author of *2001: A Space Odyssey*, is often suggested as the faker of the Apollo footage.

However, his biography clearly shows[4] that his whereabouts at the time when he was supposed to be shooting the Apollo fakery were well-known. He was busy shooting *2001* from 1964 to 1968 and then focused on the preproduction of *Napoleon*, which was never completed because United Artists went broke, and on directing *A Clockwork Orange* (1971).

4 *Moon Hoax? No thanks!* (in Italian), Diegocuoghi.com.

Famous for his obsessive attention to image composition and cinematography and for his glacially slow production pace, Kubrick simply wouldn't have had the time to direct the dozens of hours of moonwalk footage needed to cover six Moon landings (leaving aside the problem of how to fake them with 1960s visual effects technology).

Moreover, since the early Sixties, Kubrick no longer lived in the United States. He lived in the United Kingdom, where he shot all of his movies (including *2001*) and had a well-known fear of travel, especially in aircraft. This would have made it impossible for him to shoot the hypothetical fake footage in the United States and would have required the movie set to be located in the UK, with all the complexities and higher risk of leaks entailed by shooting in a densely populated country instead of using remote locations in the US.

Stanley Kubrick was probably aware of the allegations of his involvement in a movie simulating the Moon trips, so it is probably not coincidental that Danny, one of the key characters in Kubrick's 1980 movie *The Shining*, wears a sweater that depicts a rocket and the words *"Apollo 11 USA"* (Figure 10.3-1).



Figure 10.3-1. Danny wears an Apollo-themed sweater in The Shining *(1980).*

Some Moon hoax theorists, such as Jay Weidner, instead argue that this choice of sweater isn't an in-joke but is actually a silent act of confession by Kubrick, therefore bizarrely justifying one conspiracy claim by means of another one.[5]

5 *Secrets of the Shining*, Jayweidner.com, 2009.

Arthur C. Clarke, co-writer of the *2001* screenplay with Kubrick, certainly knew about these theories, since he even wrote a facetious letter to NASA's chief administrator, demanding prompt payment for the job.

> *Of course there are lunatics who don't believe we ever went there. (Well, some of them may be only pretending to be lunatics.) Recently I was sent a news-story in which it was claimed that the whole Apollo Project took place in a Hollywood studio - and that I wrote the script! This was too good an opportunity to resist, so I wrote to the NASA Administrator as follows:*
>
> *Dear Mr Goldin,*
>
> *On checking my records, I see that I never received any payment for this script. Will you please look into the matter urgently? Otherwise I will have to hand it over to my lawyers, Messrs Geldsnatch and Blubberclutch.*
>
> *I'm still waiting for an answer from Dan...*[6]

Perhaps the most astute objection to the claim that Kubrick shot the fake visual record of the Apollo missions has been suggested by Christian Blauvelt of Hollywood.com: *"the moon footage would have looked a hell of a lot better if Kubrick really had directed it."*[7]

Kubrick's legendary perfectionism has also suggested other humorous rebuttals to the conspiracy theories that involve him, as shown in Figure 10.3-2.

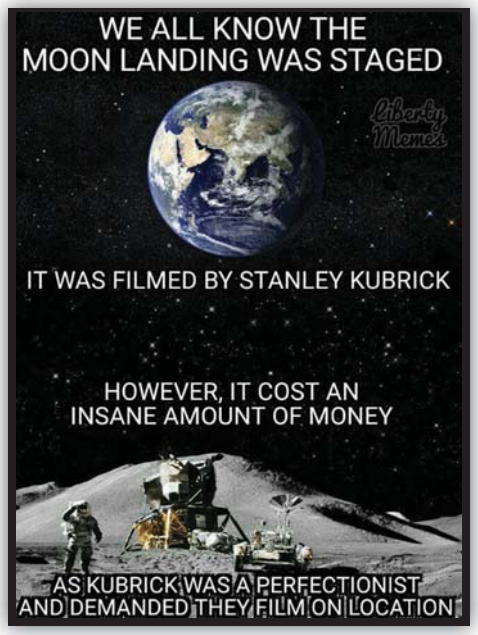


Figure 10.3-2. A meme referencing Moon hoax theories and Stanley Kubrick.
Source: Me.me.

Many believers in conspiracy theories underestimate the difficulty of producing a flawless movie fakery that could stand the test of time, being watched for decades by experts who would inspect every detail of the footage. Even Kubrick himself made mistakes in shooting *2001: A Space Odyssey*.

For example, in addition to the incorrectly billowing moondust already mentioned in Section 3.11, in the well-known *Blue Danube* docking sequence of the movie Kubrick optically shrunk the size of the Orion space shuttle with respect to the other footage of this vehicle so that the space station towards which it was flying would appear larger and more impressive. This size mismatch, however, was spotted by very attentive fans.

6 *Keynote address by Arthur C. Clarke (19 July 1999)*, Un.org. "Dan" is a reference to then NASA Administrator Dan Goldin.

7 *Get Thee to the Geek: 20 Things You Didn't Know About 2001: A Space Odyssey*, Hollywood.com, 2013.

10.4 Did the Apollo astronauts never leave Earth orbit?

IN A NUTSHELL: *No. They would have been spotted by any amateur astronomer.*

THE DETAILS: A popular twist on the Apollo fakery claims is the idea, championed for example by Bart Sibrel, that the Apollo astronauts did indeed go to space on their Saturn V rockets and returned with the splashdowns that the world watched on TV, but didn't go all the way to the Moon: they hid in Earth orbit.

In this way, it is argued, they didn't have to cope with the allegedly lethal radiation of the Van Allen belts and they were able to shoot the TV and film footage in which they are seen to be weightless inside the spacecraft. This solved the problem of simulating weightlessness, and only the footage on the Moon would have to be faked, greatly reducing the workload and the number of participants involved in the hoax. The spacecraft would actually be fully functional and would actually fly, and only a small group of people would need to know the actual flight plan.

The liftoff would be real, and so would the reentry, and the astronauts would actually be in space, where nobody could bump into them by mistake and where they would be subjected to the physiological effects of weightlessness.

Conspiracy theorists make it sound easy, but this scenario clashes with the basic fact that the lunar TV and film footage of the Apollo missions was nevertheless impossible to fake with 1960s-era movie effects.

There's also the problem that the astronauts' radio and TV transmissions would arrive from Earth orbit instead of from deep space, and this would entail a very conspicuous difference in the aiming of any radio antenna that received these signals all over the world (in California, Australia and Spain).

A full orbit around the Earth below the Van Allen belts lasts no more than a couple of hours and therefore the antennas would have to swing rapidly to chase the astronauts' spacecraft as it moved across the sky, whereas real lunar transmissions would instead require them to stay trained on the Moon, following it in its slow crossing of the sky.



Figure 10.4-1. What's a Lunar Module doing in Earth Orbit? Nothing mysterious: it's a photo from the Apollo 9 test flight. Photo AS09-21-3183.

Any wrong aiming would be obvious not only to local technicians but also to anyone nearby, who would wonder why the giant dish-like antennas were not pointed at the Moon.

Moreover, the Soviets, who were competing with the United States for the prestige of the first Moon landing, would have been able to detect the fakery by using their own radio telescopes.

Ham radio operators such as Sven Grahn, who listened in on the radio transmissions from the Apollo spacecraft, also would have noticed that the signals were not coming from the Moon or its vicinity: they would have found that the signal vanished periodically when the spacecraft, as it orbited around the Earth, went beyond the local horizon.[8]

8 *Tracking Apollo-17 from Florida*, Sven Grahn, Svengrahn.pp.se.

There's another objection that renders the Earth-parking scenario visibly absurd: the Apollo spacecraft would have been observable from the ground by any amateur astronomer. Even small telecommunications satellites can be spotted because they reflect sunlight and therefore stand out as bright moving specks against the dark sky after sunset or before dawn. A vehicle of the size of Apollo (with or without the S-IVB stage) would have been very easy to spot, giving away the secret.

For example, the International Space Station, the Chinese space stations of the Tiangong series or the Russian Soyuz and American Dragon spacecraft, which orbit the Earth at much higher altitudes than those alleged for the Apollo spacecraft, are easily visible to the naked eye as rapidly moving bright points of light and can be photographed in detail with a good telescope (as demonstrated magnificently by Thierry Legault's images at Astrophoto.fr) and their transit times and paths are easily available on the Internet or via dedicated apps.

The Apollo spacecraft, therefore, would have been easy to spot from the ground for the entire duration of their flight. They would have crossed the sky as bright dots in a few minutes, inevitably attracting the curiosity and attention of professional and amateur astronomers. A good telescope would have allowed to photograph them and identify their features.

Indeed, the Apollo flights were spotted in this way not only during their stay in Earth orbit but also during their journeys to the Moon and back by professional and amateur astronomers all over the world.

The photographs shown in Figure 10.4-2, for example, were taken by the Smithsonian observatory in Maui on December 21, 1968 and show Apollo 8, the first crewed mission to leave low Earth orbit and fly around the Moon, as

it fires its engine to accelerate toward the Moon. The subsequent dumping of the residual fuel from the S-IVB stage was even visible to the naked eye and was documented by many amateur astronomers in the United Kingdom.



Figure 10.4-2. Ignition of the S-IVB stage of Apollo 8. Credit: Smithsonian observatory, Maui.

During the Apollo 13 crisis, the initial explosion released a cloud of oxygen that was documented visually from Earth. NASA, moreover, had to resort to help from the professional astronomers of the Chabot observatory in Oakland to determine the exact position of the crippled spacecraft so as to calculate the last firing of the lunar module engine, used as an emergency retrorocket, and bring back safely the three astronauts.[9]

9 *Telescopic Tracking of the Apollo Lunar Missions*, Bill Keel, Ua.edu.

Figure 10.4-3 shows, at the center, the Command Module, the Service Module and the Lunar Module of Apollo 13, over 23,000 kilometers (14,300 miles) from Earth, en route to the Moon, before the accident. The other four dots are the fairing panels that enclosed the Lunar Module and had been jettisoned.



Figure 10.4-3. The Apollo 13 spacecraft en route to the Moon. Credit: James W. Young.

The picture was taken on April 12, 1970 through the 60-centimeter (24-inch) telescope at Table Mountain, in California. The diagonal streaks are stars, distorted by the motion of the telescope to chase the spacecraft during the five minutes of the exposure of the film. The same observatory saw the Apollo 8 S-IVB stage and command and service module when they were nearly 320,000 kilometers (200,000 miles) from Earth.[10]

It should be noted that the locations and events reported and recorded by amateur and professional astronomers correspond perfectly to the ones described in NASA's technical documents for the individual missions.

10 *The Apollo 13 CSLM*, W7ftt.net.

10.5 Did the radio and TV signals come from space, but not from the Moon?

IN A NUTSHELL: *No, they actually came from the locations stated by NASA. If they had originated anywhere else, the Soviets, ham radio users and anyone near a receiving station would have noticed easily.*

THE DETAILS: A frequent conjecture among Moon hoax theorists is that the live TV broadcasts and the radio communications were prerecorded and then sent from an uncrewed satellite that orbited the Earth or the Moon or was somewhere on the lunar surface.

An Earth-orbiting satellite would have been out of the question, because the Soviet space surveillance system and ham radio users worldwide would have been capable of intercepting the direct feed from the satellite and would have realized that its signal wasn't coming from the Moon because its source changed position very quickly (a satellite in Earth orbit would rise and set over a given location in a matter of minutes). Even a geostationary orbit would have revealed the trick, because it wouldn't have followed the slow orbital motion of the Moon.

Placing the transmitter in orbit around the Moon or on the lunar surface would have solved these problems, but it would have left another very conspicuous clue to the fakery: the so-called *Doppler effect*.

The radio frequency of the transmissions from a spacecraft traveling through space varies depending on the speed with which it moves toward or away from the receiving station, just like the sound of an ambulance siren changes pitch as it approaches or moves away. This variation, known as *Doppler effect*, would have been detectable by any well-equipped radio enthusiast.

The transmitter would therefore have had to travel through space (or vary its transmission frequency artificially) so as to follow exactly the mission profile stated by NASA, simulating not only the trip but also every lunar orbit, which entailed an increase and a decrease in the distance to Earth and therefore a consequent continuous frequency variation.

A second transmitter, simulating exactly the movements of the Lunar Module when it detached from the Command and Service Module, landed on the Moon and lifted off from the lunar surface, would also have been necessary.

To add to the complexity of this concept, it would have been necessary to transmit not only the radio and TV communications but also fake telemetry data that reported the state of the spacecraft to Mission Control. All these

data would have to be created from scratch with perfect authenticity and would have to match exactly the speed and direction of the spacecraft, which would have been detectable by means of the Doppler effect.

Worse still, any mistake in the characteristics of the transmissions from the fake spacecraft would have exposed the conspiracy.

Moreover, the deep space monitoring and transmission network wasn't entirely controlled by NASA or the US government. For example, most of the radio communications of the various missions and in particular the live TV broadcast of the first landing on the Moon went through the Australian radio telescopes of Parkes and Honeysuckle Creek, which were operated by local engineers.



Figure 10.5-1. Mike Dinn in 1968. Photo credit: Hamish Lindsay. Scan credit: Colin Mackellar.

These engineers weren't nameless minions; they were (and many still are) very real people, who don't mince words about their role in the Apollo project and about the conspiracy theorists who accuse them of collusion. Here's what Mike Dinn, deputy manager of the radio monitoring station of the Manned Spaceflight Network in Honeysuckle Creek, Australia, during Apollos 7 to 13, has to say:

> *...as I was the Australian citizen employed by the Australian government responsible for running the operations at the prime Australian tracking site here near Canberra I can vouch for the scientific/ engineering fact that we pointed our antenna at the trajectory to, at and from the moon and transmitted and received radio signals containing commands, telemetry, television together with navigation info from antenna angles, Doppler frequencies and two way range delays. Impossible to fake.*
>
> *– interview with Mike Dinn by Steven Dutch*

> *I actually talked with Apollo 8 on the way out (see ALSJ for details) and my assistant ops man John Saxon spoke to Young and Duke on the lunar surface during Apollo 16.*
>
> *– my personal communication with Dinn, 2010*

10.6 Were the alleged mistakes left in on purpose by whistleblowers?

IN A NUTSHELL: *No. They're so obvious that their supervisors would have noticed them.*

THE DETAILS: One of the most interesting and creative justifications in the alternative vision of reality proposed by conspiracy theorists, both regarding the Moon landings and other historical events, is the so-called *whistleblower theory*.

Sooner or later the conspiracy theorist has to deal with the fact that there are, paradoxically, just *too many* apparently revealing mistakes in his reconstruction of the events. If this was supposed to be a colossal deception, organized by the highest levels of government, with access to vast funding and resources and top experts in fakery, and if the nation's reputation was at stake, why is the resulting conspiracy riddled with blatant blunders and amateurish mistakes?

A typical answer to this conundrum is to explain away the missing stars and fluttering flags by arguing that these flubs were left in *intentionally* by the perpetrators of the conspiracy. They were ashamed of the deception into which they had been forced and so they tried to warn people through these mistakes. Astute observers and true free thinkers would detect these coded messages and reveal the truth to the world.

The logical flaw of this explanation is that it uses a totally unproven conspiracy theory to prop up another conspiracy theory and it implies that the supervisors of the fakery were so dumb that they didn't notice the telltale mistakes that had been left in by the whistleblowers. It is rather difficult to believe that nobody along the chain of command of the conspiracy would notice, for example, a letter "C" left conspicuously on a rock or the crosshairs drawn behind objects.

This conspiracy-within-a-conspiracy theory also entails assuming that all the experts in the science fields touched by the Apollo missions are blind and incompetent: today's astronauts, aerospace engineers, astronomers, including those of countries that don't exactly hold the United States in high regard, would all have to be so dumb that they fail systematically to notice the alleged intentional errors that conspiracy enthusiasts, despite knowing little or nothing about spaceflight or astronomy, claim to find so easily.

Unfortunately, people who are convinced that they are the only ones who have the insight and the intelligence to grasp the truth that is hidden to others are usually unable to abandon this pathological worldview and will often resort to an ever-expanding web of conspiracies to hold on to that

view. In such cases, arguing over details is pointless: the problem is not in the Moon landings, but in the denialist's overall mindset.

10.7 Were the Moon rocks actually meteorites collected in Antarctica by Wernher von Braun?

IN A NUTSHELL: *No. There wouldn't have been enough available, and anyway they would be different from intact Moon rocks. Any geologist would notice the difference immediately.*

THE DETAILS: Some conspiracy theorists, such as Bill Kaysing, allege that the Apollo Moon rocks were not retrieved by astronauts on the Moon but were picked up in Antarctica by rocket designer Wernher von Braun.

It is true that meteorites can be found in Antarctica, since they stand out very clearly against the frozen white surface. The same is true for any surface that is naturally free from rocks, such as sandy deserts.

It is also true that some of these meteorites come from the Moon by natural means: for example, a larger meteor that strikes the lunar surface can hurl debris powerfully enough to escape the Moon's gravitational influence and drift through space until it is captured by the Earth's far stronger gravity pull. The meteor then falls through our planet's atmosphere and hits the ground.

It is also factually correct that von Braun went to Antarctica in 1966-67 together with other NASA management members. This was no secret: it was reported widely at the time (for example in *Popular Science* no. 5, May 1967).

But there are major holes in this conspiracy theory. First of all, why send a very well-known and conspicuous von Braun looking for meteorites, when NASA had plenty of expert geologists who could identify meteorites far more confidently than a rocket engineer and could do so without attracting attention?

Secondly, meteorites in Antarctica are few and far between; *lunar* meteorites that happen to land there are even rarer. NASA's Antarctic meteorite collection only has 25 as of January 2017. It would have been impossible to collect enough lunar meteorites to fake the 382 kg (842 lb) of Moon rocks brought to Earth by Apollo astronauts.

Moreover, any meteorite found on Earth is altered profoundly by its high-speed, searingly hot dive through the atmosphere. Its surface is partly melted, eroded and smoothed. Once on the ground, it is affected by weathering and chemically altered by interaction with air. Apollo rocks are instead jagged and pristine, and their surface exhibits microscopic craters produced by the highly energetic impact of micrometeoroids.

Could the NASA Moon rocks have been faked by collecting lunar meteorites from Antarctica and then removing their outer layer to give them a jagged shape? No. The outer layer of Moon rocks contains large amounts of helium-3, which is very rare on Earth. This layer is also affected by the particles of solar wind as rocks lie on the lunar surface. Removing this outer layer would remove these features, and this would be evident to any geologist.



Figure 10.7-1. A meteorite found in Antarctica. Credit: ANSMET, 2017.

11 UFOs and Moon landings

One of the many contradictions of Moon hoax theories is that some claim that the Apollo landings never happened, while others argue that the Apollo flights not only did happen but even encountered extraterrestrial spacecraft and there were even secret missions to the Moon.

It's important to be acquainted with these theories of secret flights and alien encounters, because they are part of the classic repertoire of hardcore conspiracy theorists and reveal very clearly the typical errors of the conspiracist mindset.

Most importantly, however, they're very amusing to bring up in a Moon hoax discussion and then watch the ensuing colorful argument among the various factions of conspiracy theorists.

11.1 Are there UFOs in Apollo photographs?

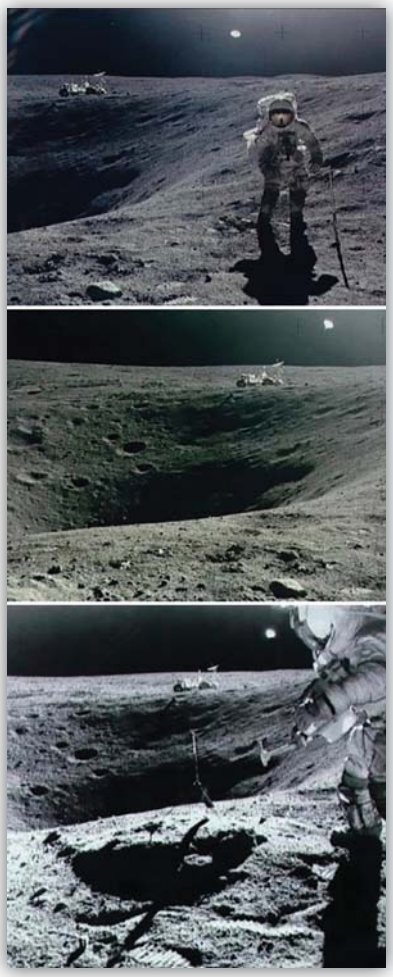


Figure 11.1-1. Alleged UFOs in Moon photographs according to Ufocasebook.com.

IN A NUTSHELL: *No. The objects claimed to be UFOs are actually lens flares or spacecraft debris.*

THE DETAILS: Some UFO enthusiasts claim that the photographs taken on the Moon by the astronauts show the presence of alien vehicles. For example, Ufocasebook.com includes, in the section entitled *The Best UFO Pictures Ever Taken*, three photographs of the Apollo 16 mission (Figure 11.1-1).

It's worth noting that the people who present these photographs as evidence of a UFO-related conspiracy claim that they were *really* taken on the Moon and therefore implicitly contradict the other conspiracy theorists who deny the Moon landings.

The "UFOs" that can be seen in these photographs and in many other images from the Apollo missions are not flying saucers that NASA nonchalantly left in the pictures, hoping that nobody would notice them: they're simply reflections of the Sun inside the camera lens. These reflections are known to photographers as *lens flares* and occur on Earth, too, although usually they are less noticeable because on Earth the sky is very bright when the Sun is up and therefore the flares fall onto a bright background. On the Moon, the sky is black even when the Sun is above the horizon, so any lens flare stands out starkly against the blackness.

The photos shown in Figure 11.1-1 are, top to bottom, AS16-114-18423, AS16-114-18422 and AS16-109-17804, all from the Apollo 16 flight. They're incomplete versions of those images, cropped so as to not show an important detail.

It turns out that in the uncropped high-resolution original scans of these photographs, the "UFOs" are actually two in each image and are always aligned in the direction of the Sun, the position of which can be determined by tracing the directions in which the shadows converge. These are typical indications of a lens flare.

In the third photo, in particular, the lens flare would stand out unmistakably if someone hadn't trimmed off the upper part of the picture, because the second "UFO" is actually *in front* of the sunshade on the astronaut's helmet (Figure 11.1-2).

It's rather hard to believe that the pictures were cropped so conveniently just by chance or that the vehicles used by aliens for their Moon trips are the size of horseflies.

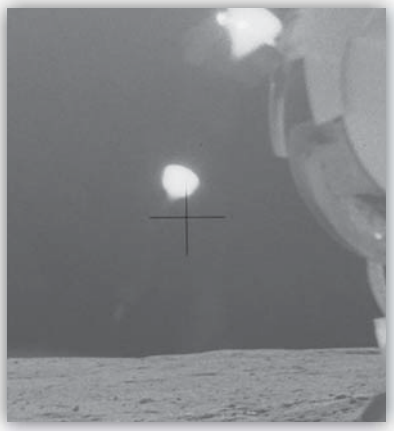


Figure 11.1-2. Detail of photo AS16-109-17804, including the part that is cropped in the version shown by Ufocasebook.com. Note the raised sunshade on the helmet and another "UFO" on the sunshade.

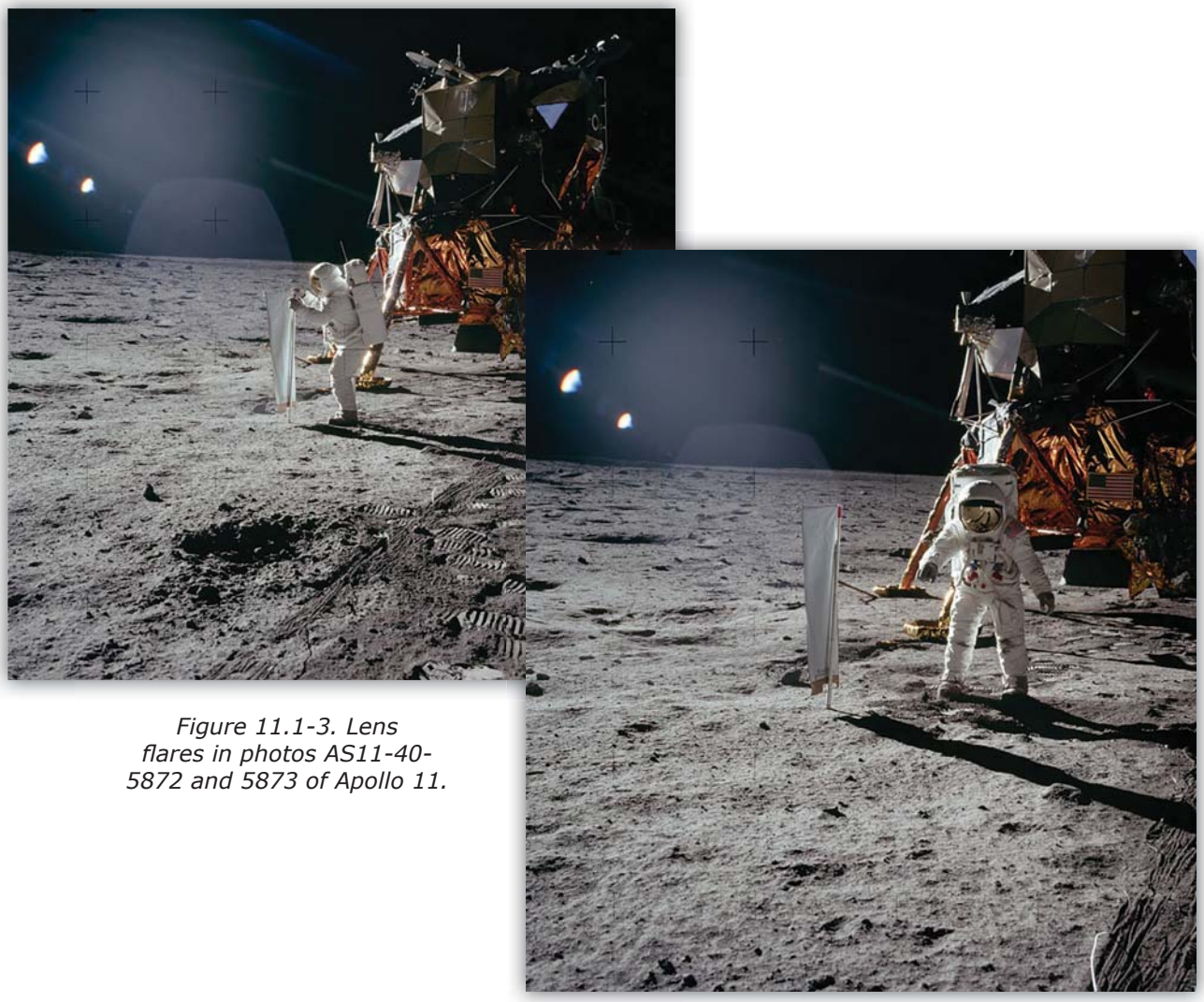


Figure 11.1-3. Lens flares in photos AS11-40-5872 and 5873 of Apollo 11.

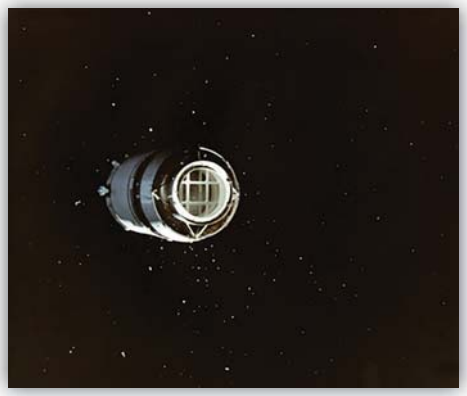


Figure 11.1-4. The third stage of Apollo 8. NASA photo AS08-16-2583.

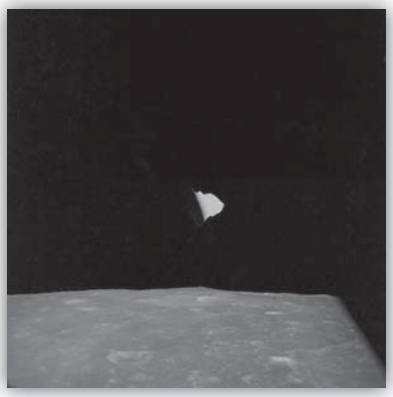


Figure 11.1-5. NASA photo AS10-28-3988 (Apollo 10).

The visual records of the Apollo flights include dozens of photographs affected by lens flares. In the color photos, such as the ones shown in Figure 11.1-3, the rainbow effect produced by the different refraction of the various colors inside the lens is an obvious giveaway that the alleged alien spacecraft is merely a byproduct of the camera lens and is not a real object.

However, not all the "UFOs" that can be spotted in the Apollo photographs are camera-generated. Some are real objects that are difficult to interpret correctly without knowing the technical context: for example, they are often parts of the spacecraft that were jettisoned after use or flakes of the vehicle's covering that peeled off and traveled alongside it by inertia.

Fragment break-off was quite frequent. Figure 11.1-4 shows the S-IVB stage of Apollo 8 after its separation from the Command and Service Module: note the swarm of bright debris that surrounds the jettisoned stage.

Figure 11.1-5 instead shows a piece of Mylar covering that detached from the Apollo 10 Command Module and floated outside the spacecraft. Astronaut John Young estimated it to be about 50 centimeters (a foot and half) long.

Without knowledge of this context and with no distance references to estimate the size of the object, it's easy to imagine the flake to be a mysterious alien vehicle. It is not surprising that this is one of the most frequently mentioned Apollo images among UFO enthusiasts. However, a more thorough perusal of the Apollo archives reveals at least two more photographs (AS10-28-3989 and 3990) of the same fragment as it slowly turns. If these photos are combined to create a stereo pair, they clearly show that the object is small and close to the viewer.

11.2 Did Buzz Aldrin see a UFO?

IN A NUTSHELL: *No. He saw a discarded part of the Apollo spacecraft. He said so immediately upon returning to Earth, but conspiracy theorists and unscrupulous documentary makers ignore or even edit out his explanation.*

THE DETAILS: This remarkable claim stems from a statement made by Buzz Aldrin (Apollo 11) in the documentary *First on the Moon: The Untold Story* (2005). Here's what he says verbatim:

> *There was something out there that was close enough to be observed... and what could it be?... Mike* [Collins] *decided he thought he could see it in the telescope, and he was able to do that, and when it was in one position it had a series of ellipses. But when you made it real sharp it was sort of L-shaped.*
>
> *That didn't tell us very much... Obviously the three of us were not gonna blurt out "Hey, Houston, we've got something moving alongside of us, we don't know what it is, you know, can you tell us what it is?" We weren't about to do that! 'Cause we know that those transmissions would be heard by all sorts of people, and who knows what somebody would have demanded that we turn back because of aliens or whatever the reason is. So we didn't do that, but we did decide we'd just cautiously ask Houston where... how far away was the S-IVB...*
>
> *And a few moments later, they came back and said something like it was six thousand miles away because of the maneuver, so we really didn't think we were looking at something that far away, so we decided that after a while watching it, it was time to go to sleep, and not to talk about it anymore until we came back, in debriefing.*

Aldrin's expression clearly reveals his amusement (Figure 11.2-1) as he tells this anecdote; he doesn't speak in the solemn tone that one might expect for such a world-shaking revelation as an alien encounter. Nevertheless, the documentary dwells on his words and also shows a blurry image of an object (not the one seen by Apollo 11, but another one observed during another Moon trip) while the narrator states that the object seen by Aldrin was never identified certainly.



Figure 11.2-1. Buzz Aldrin recounts his "UFO" encounter in First on the Moon: The Untold Story (2005).

At first sight, it would seem that an Apollo astronaut is claiming that he saw an extraterrestrial spacecraft and decided, together with his crewmates, to keep quiet about it. That's the way many UFO sites present this story. But a little fact-checking reveals that the conspiracy of silence was perpetrated not by the astronauts, but by the authors of the documentary, perhaps seeking a dramatic scoop.

The most likely and thoroughly non-extraterrestrial explanation of the sighting had in fact been given directly by Aldrin during the interview he recorded for the documentary, but it was cut, as Aldrin told David Morrison of the NASA Astrobiology Institute[1], and continues to this day to be ignored by the media.

1 *Ask an Astrobiologist*, 26 July 2006, Nasa.gov.

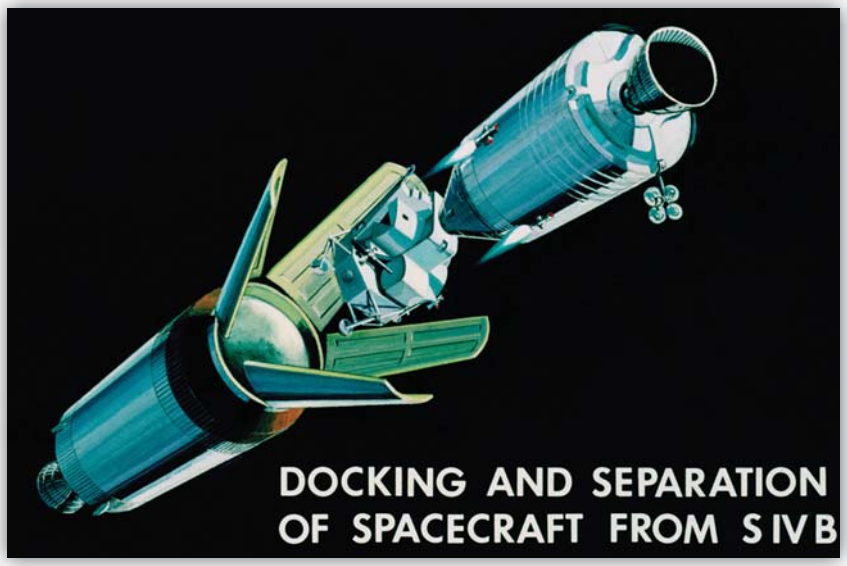


Figure 11.2-2. Extraction of the Lunar Module. Detail of NASA drawing S-66-5107.

The astronaut explained to the documentary makers that the object that was chasing them was quite likely to be one of the four fairing panels that enclosed the Lunar Module (LM), as shown in Figure 11.2-2.

During liftoff from Earth and for the initial part of the trip to the Moon, the LM sat on top of the S-IVB stage (the cylinder at the bottom left in Figure 11.2-2) and below the Command and Service Module (CSM), protected by these four panels.

As the spacecraft continued its voyage toward the Moon, the CSM separated from the S-IVB stage and turned around to face the stage. The fairing panels opened out and detached from the S-IVB and then the CSM docked with the LM and pulled it away from the stage.

The docked CSM and the LM (the actual Apollo spacecraft) then moved away from the S-IVB, which was commanded from Earth to fire its engines to set it on a trajectory that avoided any risk of collision with the spacecraft.

The fairing panels, however, were already uncoupled from the S-IVB stage and therefore were not affected by the trajectory change and diligently obeyed Newton's laws of motion, continuing by inertia along the same path as the Apollo spacecraft, like seagulls trailing a ship, until the spacecraft fired its main engine to change course.

Aldrin subsequently confirmed the true nature of the sighting on several occasions, for example on the *Howard Stern Show* of August 15, 2007, in a TV interview for the Science Channel in which he asked for the opportunity to explain to the viewers that he had not seen an alien spacecraft (the TV channel refused his request), and in a Reddit *Ask Me Anything* in 2015, when he wrote the following:

> *On Apollo 11 in route to the Moon, I observed a light out the window that appeared to be moving alongside us. There were many explanations of what that could be, other than another spacecraft from another country or another world - it was either the rocket we had separated from, or the 4 panels that moved away when we extracted the lander from the rocket and we were nose to nose with the two spacecraft. So in the close vicinity, moving away, were 4 panels. And i feel absolutely convinced that we were looking at the sun reflected off of one of these panels. Which one? I don't know. So technically, the definition could be "unidentified."*
>
> *We well understood exactly what that was. And when we returned, we debriefed and explained exactly what we had observed. And I felt that this had been distributed to the outside world, the outside audience, and apparently it wasn't, and so many years later, I had the time in an interview to disclose these observations, on another country's television network. And the UFO people in the United States were very very angry with me, that I had not given them the information. It was not an alien.*

The tale of the astronaut who says he saw a UFO is too good to be put down and so it continues to circulate unchecked, despite the fact that the matter had already been clarified and discussed thirty-five years earlier during the debriefing mentioned by Aldrin, as recorded on pages 6-33 to 6-36 of the *Apollo 11 Technical Crew Debriefing* of July 31, 1969.

It's quite ironic that the astronauts, during their flight, chose not to discuss the issue over the radio because they were concerned that their remarks might be misinterpreted but this choice was then construed as evidence that they were hiding something. Just as they expected, their words were grossly misunderstood.

11.3 Did Apollo 20 secretly recover an alien spaceship?

IN A NUTSHELL: *No. The story was made up by French artist Thierry Speth.*

THE DETAILS: A popular UFO-related claim[2] is that there was a secret military mission to the Moon, named Apollo 20, that was performed by a joint Russian-American crew to recover an alien spacecraft found on the Moon.

A man named William Rutledge claims that he was one of the members of this crew together with US astronaut Leona Snyder and Russian cosmonaut Alexei Leonov. According to his tale, a Saturn V rocket departed in secret in 1976 from the Vandenberg military base in California and reached the far side of the Moon, where the photographic reconnaissance performed by Apollo 15 had discovered a giant extraterrestrial spaceship.



Figure 11.3-1. The alleged alien spaceship.

Evidence of this alien vehicle was said to be visible even in public photo atlases of the Moon, for example in the detail of NASA photo AS15-P-9625 shown in Figure 11.3-1. The alleged spaceship is the elongated sunlit shape at the center of the picture, surrounded by deep shadow.

This claim is highly implausible: if the presence of an extraterrestrial vehicle on the Moon was so top secret that it prompted a covert joint Russian-American mission, then why was its picture released to the public?[3] Since images of the far side of the Moon were available at the time only if NASA or the Soviet Union chose to publish them, it would have been trivially easy to censor them and keep the secret.



Figure 11.3-2. The alleged alien corpse shown by Italian TV program Mistero.

Rutledge's tale, however, continues with many technical details that appear quite plausible to the layperson and includes rather shocking videos, which even show a humanoid alien corpse (Figure 11.3-2) and close-ups of the extraterrestrial vehicle.

Many UFO researchers, however, have investigated Rutledge's story and shown that it is just a well-orchestrated hoax created by French artist Thierry Speth.[4]

For example, the alleged video footage of the alien spaceship includes a very terrestrial-looking spring, and in one of the videos of the interior of the Lunar Module the background can be seen through an astronaut, revealing the fact that the astronaut was superimposed using visual effects (Figure 11.3-3).

2 *Did the USA/USSR Fly a Secret Joint Mission to the Moon in 1976 To Investigate a Crashed Extraterrestrial Mothership?* Michael E. Salla, Bibliotecapleyades.net, 2007.

3 The image is available online for example in the *Apollo Image Atlas*, Lpi.usra.edu.

4 *Falso un video dell'Apollo 20*, Cun-veneto.it, 2007 (in Italian, archived at Archive.org); *An Alien with Boobies (and floating torsos)*, Forgetomori, 2008; Above Top Secret, 2010.

Moreover, the alleged alien corpse turns out to be one of Speth's sculptures and the images of the alleged "city" shown in one of the Apollo 20 videos are copied from pages and 25 of Bruce Pennington's book *Eschatus: Future Prophecies from Nostradamus' Ancient Writings*.



Figure 11.3-3. In the bottom right corner, the lower part of body of the astronaut is missing due poorly executed video effects.

In addition to these clear indications of fakery, it is technically absurd to think that a giant Saturn V rocket could depart from California without anyone noticing its thunderous liftoff and bright climb through the sky and without being spotted by the world's professional and amateur astronomers as it flew to the Moon, as occurred for the real Apollo missions.

A launch from Vandenberg, on the west coast of the United States, instead of Cape Canaveral on the east coast, would have entailed huge trajectory problems.

If launched eastward, as in real flights, the massive S-IC first stage would have fallen back onto US mainland, possibly causing injury and damage and being easily spotted, instead of plummeting into the Atlantic Ocean as usual.

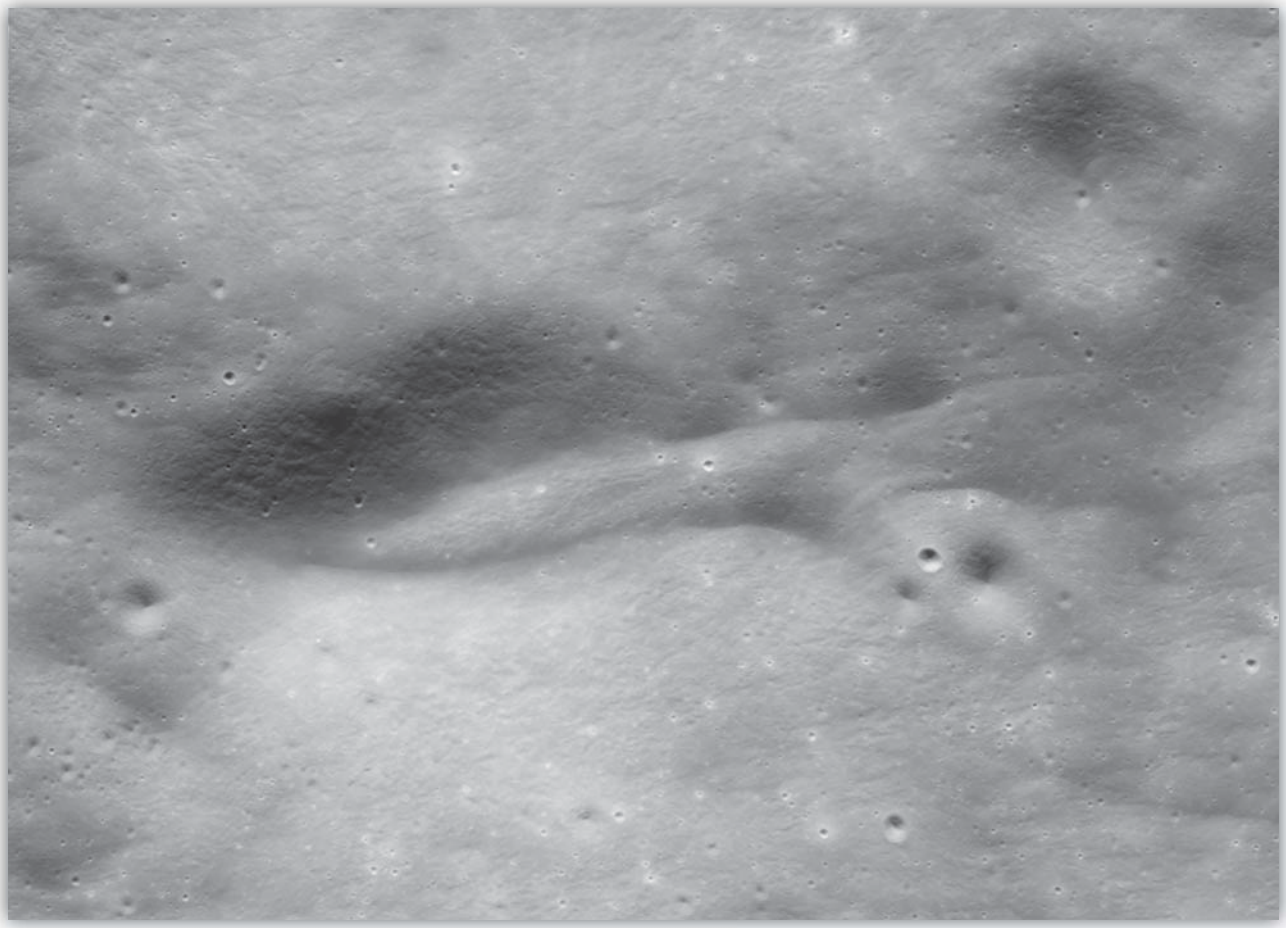


Figure 11.3-4. Detail of NASA photo AS15-P-9625. Scan from the Arizona State University archive.

If launched westward, over the Pacific, the rocket would be subjected to a huge speed penalty. Orbital rockets usually lift off along a west-to-east trajectory in order to take advantage of the substantial speed boost provided by the Earth's rotation (1470 kilometers per hour, or about 910 miles per hour, at the latitude of the Kennedy Space Center). An east-to-west Vandenberg launch would not only entail the loss of the natural boost of the Earth's rotation, but would cause an equivalent speed penalty, as the rocket would have to accelerate against the Earth's motion.

A *polar* orbit (to the north or to the south) would still have to do without the rotational boost and this would again reduce considerably the Saturn V's payload capacity.

As regards the alleged alien spaceship, the high-resolution original photographs (Figure 11.3-4) show that it's just an elongated depression of the lunar surface. The appearance of a smooth, artificial-looking shape is an artifact of the low-quality copies often used by UFO enthusiasts and hoax perpetrators. The illusion vanishes as soon as a high-quality photo is examined.

11.4 Did the astronauts find alien structures on the Moon?

IN A NUTSHELL: *No. The footage that supports this claim is taken from a 1977 British parody documentary,* Alternative 3*.*

THE DETAILS: One of the many UFO-centered tales regarding the Apollo missions alleges that Neil Armstrong and Buzz Aldrin, the two moonwalkers of Apollo 11, found alien artifacts on the Moon. Overwhelmed by their discovery, they started reporting it excitedly to Mission Control over the public radio link, while Mission Control tried to shut them up and told them to switch to a secure channel.

According to the proponents of this story, the radio transmissions from the Moon had a built-in delay designed to allow censorship and so the discovery was never made public. Allegedly, however, some radio enthusiasts managed to intercept the direct radio signal from the Moon and recorded it, and so the amazing extraterrestrial discovery was leaked.

Here's the transcript of the astronauts' excited exchange, which is also available as an audio file:

> *Astronaut 1: Hey, Houston, do you hear me?* [garbled] *we have here now.*
>
> *Houston: We have it.*
>
> *Astronaut 2: What is it? We have some explanation for that?*
>
> *Houston: We have none, don't worry, continue your program!*
>
> *Astronaut 1: Oh boy it's a, it's, it, it is really something* [garbled] *fantastic here, you, you could never imagine this!*
>
> *Houston: Roger, we know about that, could you go the other way, go back the other way!*
>
> *Astronaut 1: Well it's kind of* [garbled] *ha, pretty spectacular... God... what is that there?*
>
> *Astronaut 1: It's* [garbled]*, what the hell is that?*
>
> *Houston: Go Tango, Tango!*
>
> *Astronaut 1: Ha! There's kind of light there now!*

Houston: Roger, we got it, we [garbled]*, lose communication, Bravo Tango, Bravo Tango, select Jezebel, Jezebel!*

Astronaut 1: ...ya, ha! ... but this is unbelievable!



Capcom: O.K., I copy on that, Jack. And as long as we're talking about Grimaldi we'd like to have you brief Ron exactly on the location of that flashing light you saw...We'll probably ask him to take a picture of it. Maybe during one of his solo periods.
DMP: O.K. 96:03. Now we're getting some clear - looks like pretty clear high watermarks on this...
CMP: There's high watermarks all over the place there.
LMP: On the north part of Tranquillitatis. That's Maraldi there, isn't it? Are you sure we're 13 miles up?
Capcom: You're 14 to be exact, Ron.
LMP: I tell you there's some mare, ride or scarps that are very, very sinuous, just passing one. They not only cross the low planar areas but go right up the side of a crater in one place and a hill in another. It looks very much like a constructional ridge...

From a conversation between astronauts and Houston Control in WAV format (241 Kb):
Astronaut 1: Ha! What is it?
Astronaut 2: We have some explanation for that?
Beeping sound.
Houston: We have not, don't worry, continue your program.
Beeping sound.
Astronaut 1: Oh boy it's a... it's, it, it is really something fantastic here, you, you could never imagine this!
Beeping sound.
Houston: Roger, we know about that, could you go the other way, go back the other way!
Beeping sound.
Astronaut 1: Well it's kind of...ha, pretty spectacular ... God ... what is that there?
Beeping sound.
Astronaut 1: It's...what the hell is that?
Beeping sound.
Houston: Go Tango, Tango!
Beeping sound.
Astronaut 1: Ha! There's kind of light there now!
Beeping sound.
Houston: Roger, we got it, we watched it, lose communication, Bravo Tango, Bravo Tango, select Jezebel, Jezebel.
Beeping sound.
Astronaut 1: ... Ya, ha! ... But this is unbelievable!
Beeping sound.
Houston: We call you up Bravo Tango, Bravo Tango!

Note: Houston asked the astronauts to switch to a secret frequency, so no other outlets would be able to track the conversation between Houston and the astronauts.

Statements by astronauts:
Major Gordon Cooper.
Major Gordon Cooper said: "For many years I have lived with a secret, in a secrecy imposed on all specialists in astronautics. I can now reveal that every day, in the USA, our radar instruments capture objects of form and composition unknown to us. And there are thousands of witness reports and a quantity of documents to prove this, but nobody wants to make them public. Why? Because authority is afraid that people may think of God knows what kind of horrible invaders. So, the password still is: We have to avoid panic by all means."

Major Gordon Cooper

"I was furthermore a witness to an extraordinary phenomenon, here on this planet Earth. It happened a few months ago in Florida.
There I saw with my own eyes a defined area of ground being consumed by flames, with four indentions left by a flying object which had descended in the middle of a field. Beings had left the craft (there were other traces to prove this).
They seemed to have studied topography, they had collected soil samples and, eventually, they returned to where they had come from, disappearing at enormous speed...
I happen to know that authority did just about everything to keep this incident from the press and TV, in fear of a panicky reaction from the public."

Eugene Cernan

Eugene Cernan.

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Figure 11.4-1. A slightly different version of the alleged exchange, published in American Psychic and Medium Magazine*, January 2018, page 169.*

However, the original source of the alleged recording is actually a 1977 British parody documentary, *Alternative 3*.

Even without knowing its source, there are rather obvious clues that the exchange is fake. First of all, the voices in the recording are completely different from Armstrong and Aldrin's, as any comparison with their original voices will easily show.

Moreover, the dialogue doesn't follow standard protocol at all. In real Apollo mission recordings, every new communication begins with the name or callsign of the recipient followed by the name or callsign of the speaker. Astronauts begin to talk to Mission Control by saying *"Houston..."* and then identifying themselves or their spacecraft, as in *"Houston, Tranquility Base here. The Eagle has landed"*. Mission Control always begins by saying the name of the astronaut or spacecraft being called and then identifies itself by saying *"Houston"*. This is a very formal procedure, ingrained by habit in the astronauts' behavior. No such protocol is followed in the allegedly secret audio clip.

The beeps (formally known as *Quindar tones*) that separate the astronauts' voices from the orders from Mission Control are different from the real ones, and so are the background noise and the type of distortion.

Also, there's no sign of the 2.6-second delay between the voice from Mission Control and the replies of the astronauts that inevitably occurs due to the round trip to Earth-Moon distance, covered by the radio signal at the speed of light.

Another version of this exchange was published by an American-Canadian tabloid, the *National Bulletin*, on September 29, 1969, under the title *Phony Transmission*

Failure Hides Apollo 11 Discovery... MOON IS A UFO BASE! It's not clear whether this was an attempt at parody like *Alternative 3*, but it certainly has the same implausible setting and is replete with meaningless technobabble such as *"orbit scanned"* or *"In 625 to the fifth, auto-relays set"*, which might be impressive to the layperson but are dead giveaways for experts in the field.



Figure 11.4-2. Alternative 3 *(Anglia, 1977). The alleged astronaut recording begins at 24:04 [http://tiny.cc/w91eez].*

The issue of the badly faked beeps is a good opportunity to dispel two frequently repeated myths about them: they could not be heard by the astronauts and they were not used to indicate that it was the other party's turn to talk.

These beeps instead controlled the transmission of the radio signals from Earth via transmitters located in various countries, which were used as the Earth's rotation brought them within line-of-sight reach of the spacecraft. They were linked to Mission Control in Houston, Texas, via analog telephone lines, which were affected by interference and noise, so it was necessary to mute the transmitter locally, at the transmission station, instead of closing the microphone in Houston.



Figure 11.4-3. Samples of Neil Armstrong's voice during the Apollo 11 Moonwalk [http://tiny.cc/tc2eez].



Figure 11.4-4. Samples of Buzz Aldrin's voice during the Apollo 11 Moonwalk [http://tiny.cc/kd2eez].

Essentially, therefore, the Quindar tones were remote control signals sent over the telephone lines. This is similar to the "push to talk" function in walkie-talkies or ham radio equipment.

These signals are still used for some space communications. They take their name from Quindar Electronics, Inc.,which provided the equipment that generated these tones and responded to their commands. The tones are 250 milliseconds long at 2,525 Hz for the activation tone (transmission start) and 2,475 Hz for the deactivation tone (transmission stop).

A filter eliminated the tones from the signal sent to the Apollo spacecraft and therefore the astronauts usually didn't hear them. However, during some flights, such as Apollo 8, the filtering didn't always work fully and the piercing beeps reached the astronaut's ears.

11.5 What about astronaut Ed Mitchell's UFO claims?

IN A NUTSHELL: *He made it very clear that he had no* direct *evidence of contact with extraterrestrials, but trusted people who* said *they had such evidence. He never claimed that he had seen UFOs during his lunar mission and actively denied any such claim.*

THE DETAILS: Apollo 14 Lunar Module pilot and moonwalker Edgar Mitchell (1930-2016) is often presented as an authoritative UFO witness. He openly supported claims that some of the unidentified flying objects sighted since 1940 were extraterrestrial vehicles, but he also made it very clear on several occasions that he did not support claims that he saw direct evidence of extraterrestrial presence while he was in space or on the Moon or that NASA was involved in some kind of Moon landing coverup:

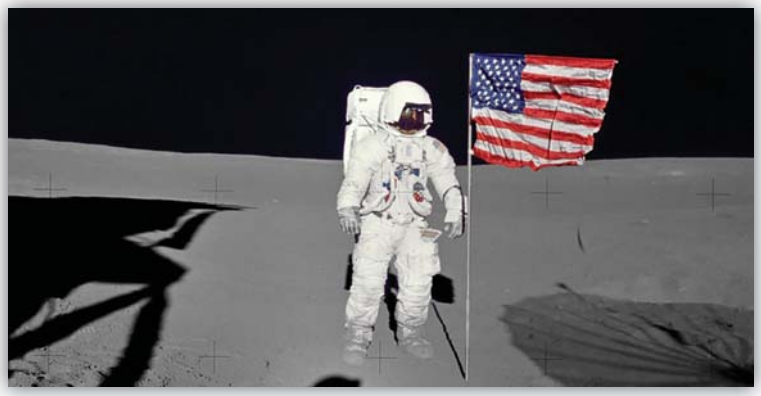


Figure 11.5-1. Ed Mitchell on the Moon.

> *The notion that there are structures on Mars or the Moon is bonkers. I can attest to the latter -- I've been there. We saw no structures at the landing site and none was reflected in my helmet, as has been alleged.*
>
> *– UFOs: It's a coverup,* by Tom Rhodes, *Ottawa Citizen,* October 11, 1998.

> *I, nor any crew I was on (I was on three Apollo crews), received any briefing before or after flights on UFO events, saw anything in space suggesting UFOs or structures on the moon, etc. We did it just like we said in official reports. My only claim to knowledge of these events is from the individuals, mostly of yesteryear, who were in government, intelligence, or military; were there, saw what they saw, and now believe it should be made public. But I claim no first hand knowledge, nor have any.*
>
> *– Ed Mitchell Most Unhappy With Greer Using His Name As Disclosure Witness,* Rense.com, 2001.

On the other hand, he went on record saying that he believed that extraterrestrial spacefarers have visited Earth and that there is a government coverup of the UFO

phenomenon (but not of the Apollo Moon landings):

> *I happen to be privileged to* [...] *be in on the fact that we have been visited on this planet and the UFO phenomenon is real, although it's been covered up by our governments for quite a long time* [...] *I have been deeply involved in certain committees and certain research programs with very credible scientists and intelligence people that do know the real inside story* [...] *The Roswell crash was real and a number of other contacts have been real and ongoing.*
>
> – *Astronaut Says Aliens Are Real,* Kerrang Radio (2008).

The evidence to back up these claims is, as Mitchell himself readily acknowledged, not first-hand and is based on statements by other people that Mitchell believed to be reliable but cannot corroborate. Currently there is no publicly available hard evidence and therefore this fascinating issue remains a matter of opinion.

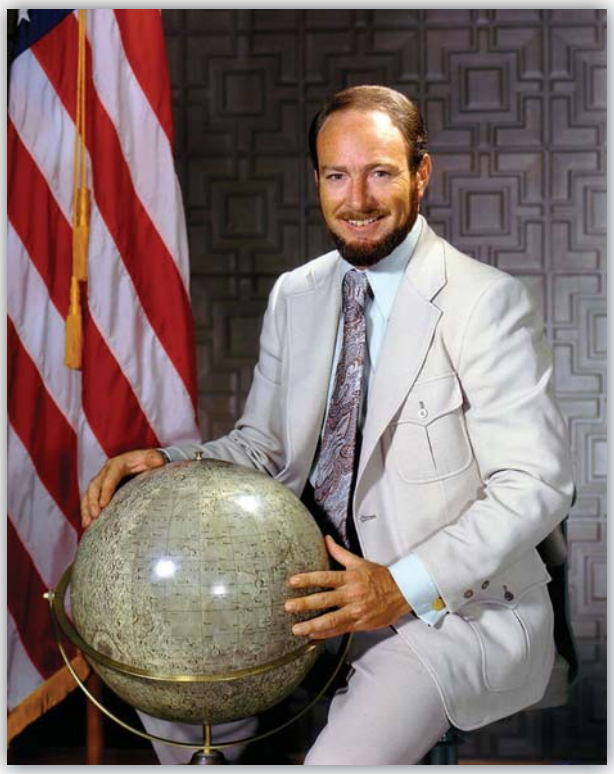


Figure 11.5-2. Ed Mitchell in 1971 (NASA/ Collectspace).

11.6 Did a lie detector test confirm the astronauts' UFO sightings?

IN A NUTSHELL: *No. Two of the astronauts were dead at the time of the alleged test.*

THE DETAILS: In April 2018, several news outlets reported that four astronauts (Buzz Aldrin, Al Worden, Ed Mitchell and Gordon Cooper) had passed "lie detector" tests regarding their claims of encounters with aliens.

However, the original source of this news report is a British tabloid, the *Daily Star*, which on 8 April published an article entitled *'I saw a UFO' Buzz Aldrin PASSES lie detector test revealing truth about aliens* by Mike Parker (Figure 11.6-1).



Figure 11.6-1. The Daily Star *presents its "exclusive" scoop.*

The article mentions an *"Institute of BioAcoustic Biology"* in Albany, Ohio, which reportedly performed *"complex computer analyses of the astronauts' voice patterns as they told of their close encounters"*. According to the *Daily Star*, *"Aldrin, Al Worden, Edgar Mitchell and Gordon Cooper all took part in the study"*.

But there's a problem with this story: two of the astronauts who allegedly *"took part in the study"* were dead at the time of the report. Ed Mitchell died in 2016 and Gordon Cooper died in 2004.

Careful reading of the article reveals that the *"analyses"* were not performed on the astronauts, as suggested initially, but merely used old recordings of their voices. This is in no way comparable to a lie detector test, which requires the subject to be present and measures several physiological parameters instead of merely analyzing the voice.

Incidentally, Cooper was involved in the Apollo program only as a backup crew member; he went to space twice with Mercury and Gemini flights, but never flew to the Moon.

Moreover, the Institute of BioAcoustic Biology has no scientific credibility: it is owned by a private individual who claims, without any evidence, that *"the frequencies contained in the voice are holographic representations of your state of health and wellness"*.

In any case, the alleged *"analyses"*, would be flawed due to two basic errors of method. The first one is that the Aldrin statement that was reportedly analyzed is his report that he saw an object during his journey to the Moon, but Aldrin has stated that the object was an Apollo spacecraft panel and not a UFO (as described in Section 11.2). The second one is that even assuming that these *"analyses"* had any scientific

merit, they would merely indicate that the astronauts believed what they said and were not lying: they would not confirm that their words were factually correct.

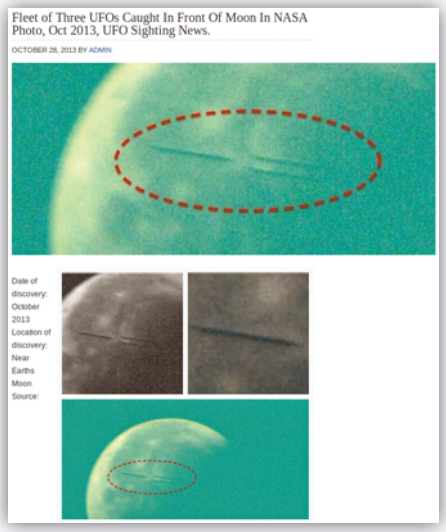


Figure 11.7-1. The alleged UFO photograph as posted by Truedemocracyparty.net (2013).

11.7 Were giant UFOs photographed in front of the Moon during Apollo 9?

IN A NUTSHELL: *No. They're the crosshairs of the sextant through which the photo was taken.*

IN DETAIL: Many pro-conspiracy theory sites have shared a photograph, claimed to be from the Apollo 9 mission, which shows three oblique linear objects in front of the Moon. These objects are described as a *"Fleet of three UFOs"* (Figure 11.7-1).

This actually *is* a photograph taken by the astronauts during Apollo 9, which did not fly to the Moon but performed a series of critical tests in Earth orbit during a ten-day flight which began on 3 March 1969. The photograph is AS09-23-3500, which can be viewed at Jsc.nasa.gov, in the *Project Apollo*



Figure 11.7-2. Photo AS09-23-3500 without processing.

Archive or at Eol.jsc.nasa.gov. The direct scan of the original film is available at Arizona State University's *March to the Moon* website.

However, the version presented by UFO enthusiasts has been heavily processed to enhance the linear objects in question. Figure 11.7-2 shows the full original, unprocessed photo.

Figure 11.7-3 is a digitally processed version based on the TIFF scan available at *March to the Moon*.

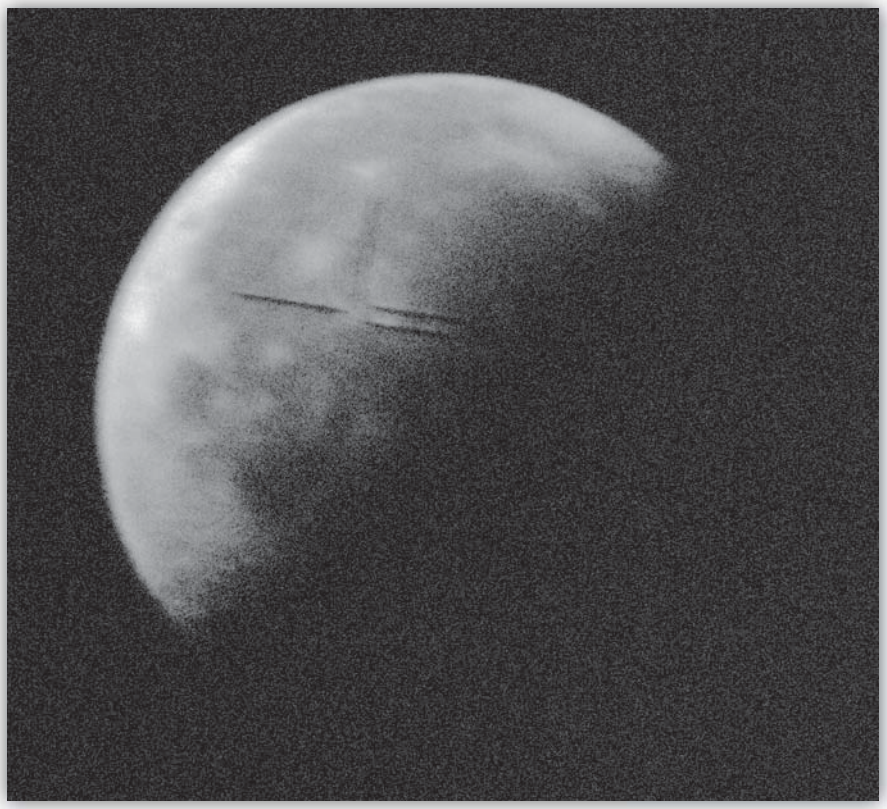


Figure 11.7-3. Digital processing enhances the linear features in photo AS09-23-3500.

These linear objects definitely occur in the original image and have not been added later by someone. However, understanding their real nature requires knowing the context in which the photograph was taken and making a few deductions.

According to NASA's Apollo 9 photograph catalog, the picture was taken at 21.50 GMT on March 10, 1969, and is described tersely on page A-94 as *"Lunar view"*.

The GAPE catalog reports that the photo was taken with an 80-mm lens: the same one used for the other photographs on the same film spool, including the ones taken directly before and after, which show views of the Earth (Figure 11.7-4).



Figure 11.7-4. Photos taken before and after AS09-23-3500, which is the first on the left in the third row.

However, a photograph taken with an 80-mm lens from Earth orbit would not have yielded such a large image of the Moon, especially with medium-format Hasselblad cameras such as those used on Apollo 9 (which used 70-mm film). This means that AS09-23-3500 was taken with a high-magnification



Figure 11.7-5. The Apollo sextant in a NASA informational video [http://tiny.cc/ygwhsz].

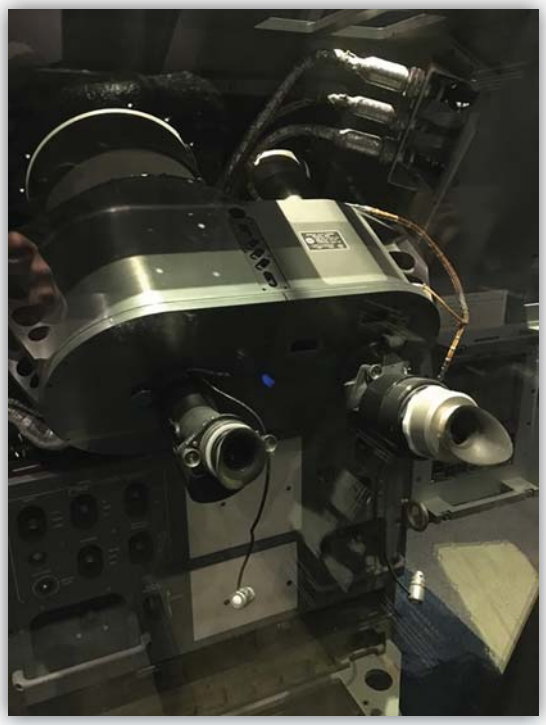


Figure 11.7-6. An Apollo sextant on display at the National Air and Space Museum. Credit: Doug Adler, Astronomy.com.

lens. But there were no suitable telephoto lenses on board Apollo 9.

It turns out that Apollo 9 actually had a sort of high-magnification lens: the one fitted to the sextant used to determine the position and attitude of the spacecraft with respect to the stars, as explained in a NASA video (Figures 11.7-5 and 11.7-6). This sextant had a 28x lens.

This sextant had a sighting reticle, shown in Figure 11.7-7, formed by lines arranged in a cross-like configuration. One of the arms of this cross was formed by two parallel lines. This shape matches quite closely the arrangement of the linear objects in AS09-23-3500. If you look at the photograph carefully, moreover, you'll notice that there are two highly blurred lines at right angles to the three darker ones.

In other words, the most plausible explanation for the mysterious linear objects is that the photograph was taken through the sextant's lens by placing the camera's lens against the eyepiece of the instrument. This inevitably included the sextant's reticle in the frame. The camera moved slightly during the shot, more or less in the same direction as the three darker lines, and therefore blurred the perpendicular ones.

The option of taking photographs through the eyepiece of the sextant had been explicitly planned and was actually used at least once during Apollo 14 for the similar COAS system installed in the Command Module.

The alleged *"fleet of UFOs"*, therefore, is not a cluster of giant extraterrestrial spacecraft but almost certainly set of tiny reticle lines of the sextant through which this unscheduled photo of the Moon was taken.[5]

5 A more detailed version of this analysis is available in the article *Nufologia: il mistero delle linee davanti alla Luna di Apollo 9* (in Italian) by the same author (2019).



Figure 11.7-7. The reticle of the Apollo sextant, as shown schematically in a NASA video.

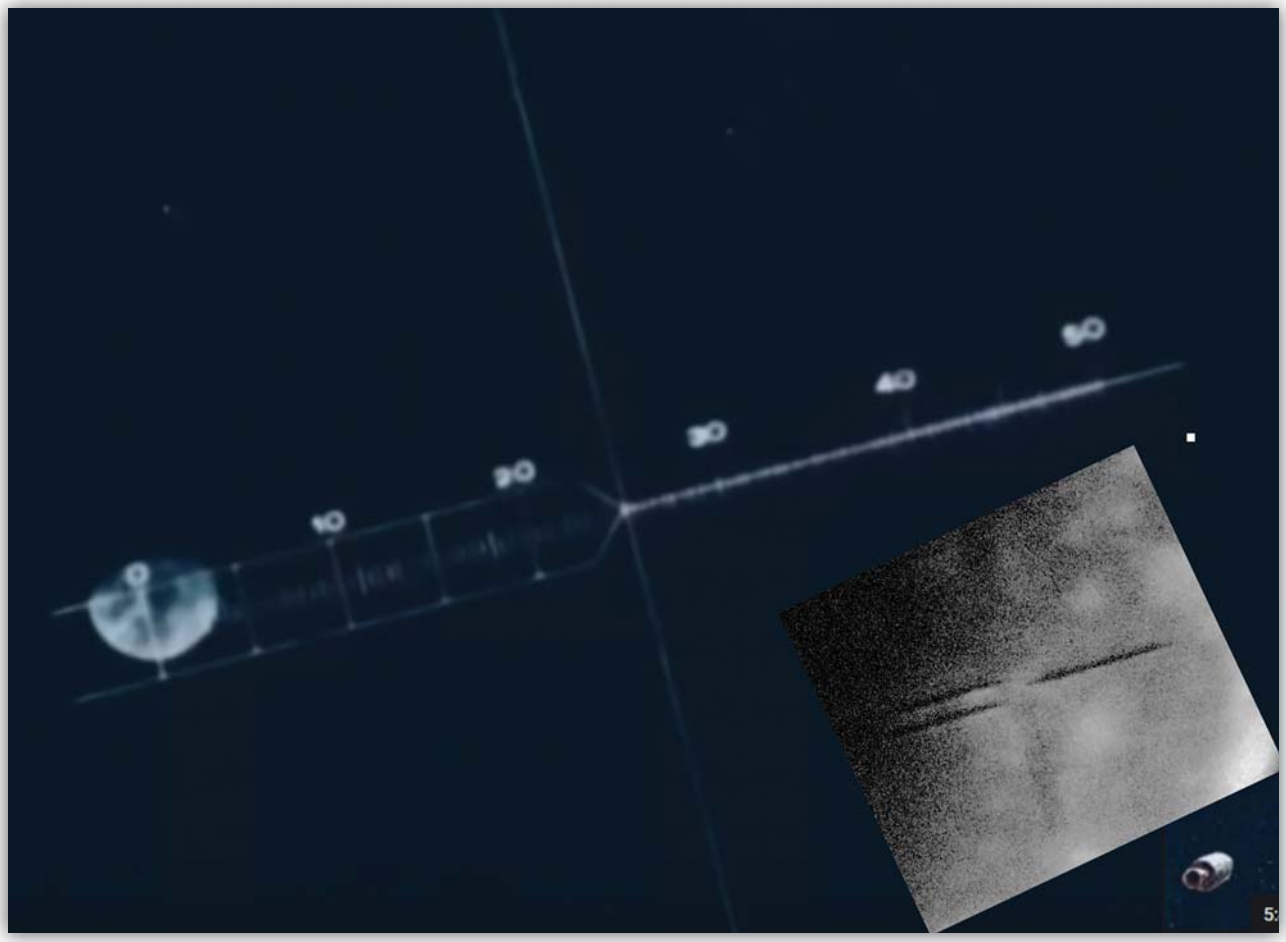


Figure 11.7-8. The reticle of the Apollo sextant compared with a detail of AS09-23-3500.

11.8 Was alien music heard during Apollo 10 and kept secret?

IN A NUTSHELL: *No. It was radio interference between the two Apollo spacecraft modules, it wasn't music at all, and it wasn't kept secret.*

THE DETAILS: It is alleged that while Apollo 10 was flying over the far side of the Moon and was out of radio contact with Earth its crew heard in their headsets *"strange music-like radio transmissions"* and that this event was kept secret for decades. In 2016, the *Huffington Post* reported this claim, noting that it was made in *NASA's Unexplained Files,* a Science Channel TV show.

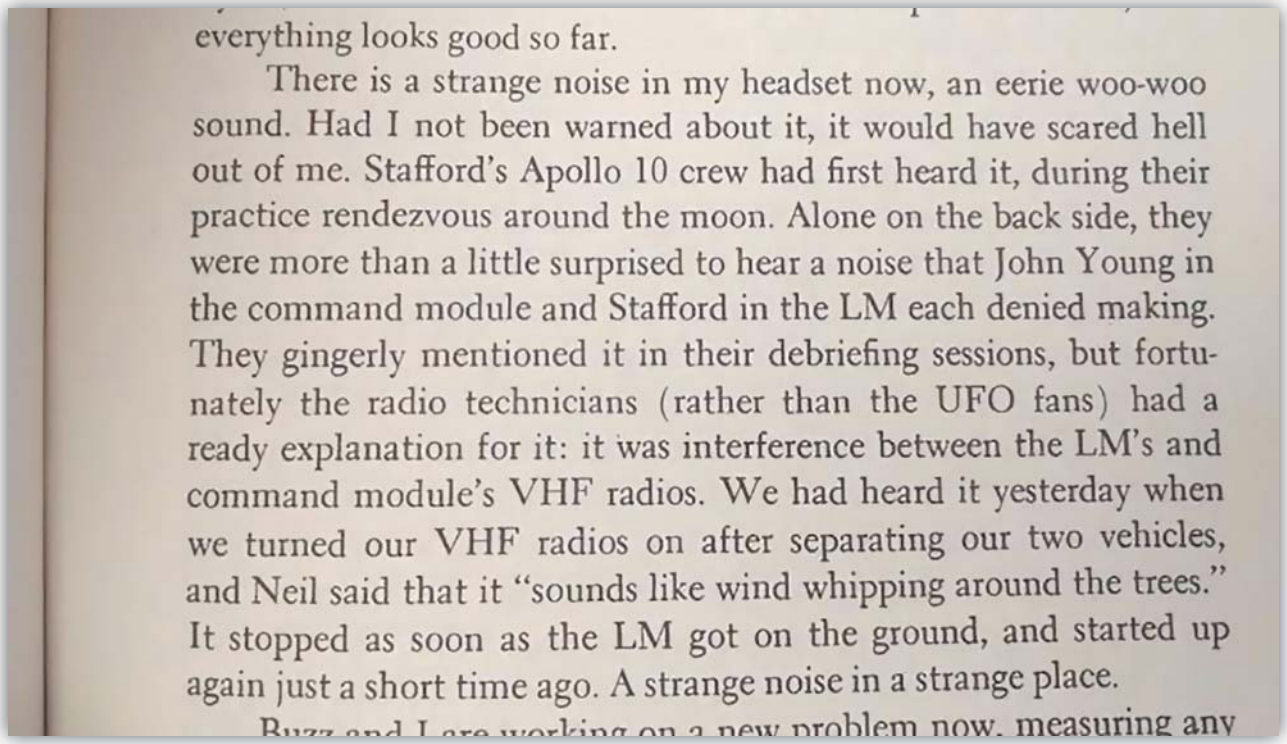
> *The crew of an Apollo mission to the moon were so startled when they encountered strange music-like radio transmissions coming through their headsets, they didn't know whether or not to report it to NASA, it's been revealed.* [...] *Almost four decades went by before lost recordings emerged that revealed something unsettling that the three Apollo astronauts had experienced while flying above the far side of the moon.* [...] *The transcripts of the Apollo 10 mission were classified and untouched in NASA's archives until 2008.*
>
> *-- Lost Tapes Reveal Apollo Astronauts Heard Unexplained 'Music' On Far Side Of The Moon*, Lee Speigel, *Huffington Post*, 20 February 2016, subsequently corrected

Actually, a little fact-checking shows that the event didn't unsettle the astronauts in any way and wasn't kept secret at all. Moreover, the recordings were never lost and the transcripts were already declassified in 1973.

John Young, who was on board Apollo 10, figured out the reason for the sounds as they were occurring: in the onboard audio recordings he can be heard noting that they are *"Probably due to the VHF ranging, I guess"*. VHF ranging was a technique which used the VHF voice radios of the spacecraft to determine the distance between the Lunar Module and the Command Module.

In other words, it was obvious even to the astronauts themselves that the sounds were coming from the Apollo spacecraft, not from some alien source. After some amusement at the unexpected noise, the astronauts resumed their work with no sign of concern.

Moreover, the Apollo astronauts certainly didn't cover up the episode. Apollo 11 astronaut Michael Collins reported it in



everything looks good so far.

There is a strange noise in my headset now, an eerie woo-woo sound. Had I not been warned about it, it would have scared hell out of me. Stafford's Apollo 10 crew had first heard it, during their practice rendezvous around the moon. Alone on the back side, they were more than a little surprised to hear a noise that John Young in the command module and Stafford in the LM each denied making. They gingerly mentioned it in their debriefing sessions, but fortunately the radio technicians (rather than the UFO fans) had a ready explanation for it: it was interference between the LM's and command module's VHF radios. We had heard it yesterday when we turned our VHF radios on after separating our two vehicles, and Neil said that it "sounds like wind whipping around the trees." It stopped as soon as the LM got on the ground, and started up again just a short time ago. A strange noise in a strange place.

Buzz and I are working on a new problem now, measuring any

Figure 11.8-1. Michael Collins explains the allegedly mysterious sound in his book Carrying the Fire*.*

detail already in 1974, and quite openly, in Chapter 13 of his book *Carrying the Fire* (Figure 11.8-1):

> *There is a strange noise in my headset now, an eerie woo-woo sound. Had I not been warned about it, it would have scared hell out of me. Stafford's Apollo 10 crew had first heard it, during their practice rendezvous around the moon. Alone on the back side, they were more than a little surprised to hear a noise that John Young in the command module and Stafford in the LM each denied making. They gingerly mentioned it in their debriefing sessions, but fortunately the radio technicians (rather than the UFO fans) had a ready explanation for it: it was interference between the LM's and command module's VHF radios. We had heard it yesterday when we turned our VHF radios on after separating the two vehicles, and Neil said that it "sounds like wind whipping around the trees." It stopped as soon as the LM got on the ground, and started up again just a short time ago. A strange noise in a strange place.*

NASA responded to the 2016 *Huffington Post* article by noting that the voice recordings and transcripts of Apollo 10 had been publicly available since 1973 to anyone who asked the US National Archives for them.[6]

6 *Apollo 10 Audio — Publicly Available Since 1970s*, Tumblr.com, 22 February 2016; NASA History Office, Twitter.com, 22 February 2016.

Additionally, listening to the original recordings and the transcripts of the astronauts' onboard conversations[7] makes it very clear that there was no actual music involved.

Onboard recording a10o-1021010, dated 23 May 1969, includes the allegedly mysterious sound, which is simply a continuous whistle. The sound is discussed briefly by the crewmembers with no sign of concern while they continue their normal work, at 2:51 and then at 7:43, as follows:

102:13:02 Cernan: That music even sounds outer-spacey, doesn't it? You hear that? That whistling sound?

102:13:06 Stafford: Yes.

102:13:07 Cernan: Whooooooooooo.

102:13:12 Young: Did you hear that whistling sound, too?

102:13:14 Cernan: Yeah. Sounds like - you know, outer-space-type music.

102:13:18 Young: I wonder what it is.

[...]

102:17:58 Cernan: Boy, that sure is weird music.

102:18:01 Young: We're going to have to find out about that. Nobody will believe us.

102:18:07 Cernan: No. It's a whistling, you know, like an outer space-type thing.

102:18:10 Young: Probably due to the VHF ranging, I'd guess.



Figure 11.8-2. NASA's reply to the Huffington Post article.

In other words, this alleged UFO mystery is based purely on poor fact-checking by a sensationalist TV show and by the *Huffington Post*. If the writers of the show or the *Post* journalist had bothered to do their research, they would have realized that this conspiracy theory had already been posted and debunked several years earlier.[8]

The *Post* later published a correction; *NASA's Unexplained Files* did not.

7 *Apollo 10 Onboard Voice Transcription*, classsified confidential in 1969 and released to the public in 1973, pages 241-242; *Apollo Flight Journal, Day 5 part 20*.

8 *Apollo 10 astronauts heard 'music' behind the Moon*, Godlikeproductions.com (2008); *Apollo 10 crew heard "music".....*, Apollohoax.net (2009).

12 How to debate a Moon hoax believer

Sooner or later we all come into contact with someone who has doubts regarding some aspect of the Apollo Moon missions or is even categorically certain that the trips to the Moon were faked. The core purpose of this book is indeed to provide a factual basis for discussion and get rid of hearsay and myths.

But when it comes to changing someone's opinion, especially a deeply rooted one, facts alone are not enough, and the situation can easily become unpleasant. This is why I have prepared this short chapter, which offers some methods of debate that can be useful in preventing the discussion from deteriorating into an argument and in ensuring that you don't waste time with people who are absolutely impervious to any fact-based reasoning.

12.1 One word of advice

***Don't*.** Never, ever try to change the mind of a Moon hoax *believer*, i.e., someone who claims to be absolutely, instinctively sure that the Moon landings were faked in one way or another. It would be a waste of time: you can't use rationality to dispel an irrational belief.

Debating a *doubter* instead can be very constructive. A doubter is still open to reasoned argument and to clearly presented evidence. Many people have doubts about the Moon landings simply because they're not familiar with the subject and have heard the hoax theories. Since they lack the tools to determine who's right and who's wrong, they take the only sensible course: they remain doubtful.

There's only one situation in which it's worth debating a Moon hoax believer: in front of a doubter. A calm, well-documented discussion will often allow the doubter to realize that the hoax believer's arguments are seductive but ultimately inconsistent and irrational.

However, some Moon hoax theories may seem quite plausible and convincing at first, and it's easy to get lost in the technical details. What you need is something that clearly reveals the absurdities of these theories.

Here is a series of questions that in my experience are effective in rapidly exposing the untenability of Moon hoax beliefs. These questions force believers to justify their ideas with explanations that they cannot give without contradicting

themselves. Moreover, they often produce a very intense and sometimes aggressive emotional reaction, which is worth a thousand pages of technical exposition in making it clear, to the doubter who observes the debate, who is rationally, serenely right and who is hopelessly, aggressively wrong.

These same questions, especially the first one, are also useful as a starting point for a debate with doubters. They force them to question the consistency and plausibility of their doubts, at least enough to want to know more about the subject, for example from the book you're reading.

To avoid writing *"he or she"* repeatedly, I'll assume that the hoax believer/doubter is male, which in any case is true most of the time. No sexism is implied; that's just the way it is in my personal experience.

12.2 If you really want to debate

If you've decided that you want to take on the challenge of a debate on Moon hoax theories, here are a few preliminary tactical suggestions.

- One of the most effective ways to flummox a Moon hoax theorist is to ask him to provide *technically documented* answers (i.e., provide specific, authoritative technical sources) to your questions – and do so without being self-contradictory. You should never accept arguments that begin with *"We all know that..."*: always ask for sources and documents to back up every claim. Without them, the theorist's claims are nothing more than hot air. Remember to always ask *"Do you have an authoritative source for that?"*

- Some hoax theorists try personal attacks by asking you if *you're* qualified to talk about the Moon landings. They might ask you if you're an aerospace engineer or have a science degree or other qualifications that entitle you to speak authoritatively. If you do, say so, of course; but in any case, make it very clear that your personal qualifications aren't really relevant, since the authenticity of the Moon landings is supported overwhelmingly by the international technical and scientific community. Then ask the conspiracists what qualifications *they* have or what authoritative backing *they* can provide. They won't have any.

- Never allow a hoax theorist to control the discussion by changing the subject and moving on to another claim when he is stumped: this is a typical trick. Be calm but firm: you've asked a specific question, you have the right to an answer. If the hoax supporter dodges the question, ask it again, and point out his attempt to elude it. If he then caves in and starts to submit another objection by saying *"Yes, but...",* remember to make it very clear that his *"Yes"* means that he's conceded the point and admitted that he was wrong (and therefore, on a positive note, you both agree on this point). Point out that if he's wrong on that point, maybe he's wrong on the others.

- Don't get bogged down in arguments over the technical minutiae of the missions: they don't provide any insight to anyone who is not well acquainted with spaceflight. Conspiracy theorists love to split hairs on insignificant details. Don't reply by offering further technical details, but ask them to get to the point. Just say *"And so?":* the hoax proponent will have to explain why the technical detail on which he is dwelling is so important. Usually he will fail, and this will show how inconsistent his vision actually is and will bring the debate back to more general and less arcane issues.

- Remember that the best way to show how ridiculous these theories are is to let a Moon hoax theorist babble on and then calmly ask a few pointed questions. Most of all, be serene. Let your tone of voice make it clear to everyone who is being sensible and logical and who is being hysterical and obsessive, and show that you don't really care whether you change his mind or not. Conspiracy theorists want you to argue and get mad: don't rise to the bait. Have fun and consider the debate an opportunity to talk about the greatness and wonder of spaceflight.

Now let's move on to the questions.

12.3 Questions for hoax believers

Please remember that I advised you not to get involved in this kind of debate: don't get mad at me if you end up falling out with a friend, colleague or teacher. Don't say that I didn't warn you.

12.3.1 If you only have time for one question

Moon hoax claims often surface in situations where there's no time to have an extensive debate. If all you have time for is one question, try this one.

> **There isn't a single astronaut, from any country, who agrees with Moon hoax theories. Many of them are personal friends of the moonwalkers or trained with them. Are you saying that these highly skilled space professionals, who have actually *been* in space, are too dumb to realize that they were being hoaxed by a bunch of liars riding a fake rocket? Are you implying that you're smarter than an astronaut? Seriously?**

If you know the name of an astronaut from your country, mention it; e.g., *"Are you implying that you're smarter than Canadian astronaut Chris Hadfield, who spent six months in space working on the International Space Station?"* Make it personal.

Then walk away or change the subject.

12.3.2 How many missions were faked?

Was it just the first Moon landing (Apollo 11), or all of them, or all the flights that went to the Moon, or maybe all crewed flights in space? What about the Soviet ones? The Chinese ones? Whatever he says, the Moon hoax theorist is going to paint himself in a corner.

If he claims that *all* the lunar flights were faked, including the ones that didn't land, then he's saying that *nine* missions to the Moon were hoaxes – not just the six lunar landings, but also Apollo 8, 10 and 13, which went all the way to the Moon and flew around it.

The complexity of faking perfectly not one, not six, but *nine* entire flights is overwhelming: the amount of photographs, movie and TV footage, radio transmissions and scientific data that would have to be simulated flawlessly increases to the point of absurdity. Likewise, the number of

people that would have to be in the know and kept gagged for over four decades, with nobody ever blabbing, becomes ludicrously large. Especially if you consider that all this incredibly complicated, top-secret trickery would have to be achieved by the US government – which, let's face it, has a less than stellar record at keeping secrets and accomplishing complex tasks.

If the conspiracy theorist claims that only the Moon landings (i.e., the Apollo flights from 11 onward except Apollo 13) were faked, then this implies that he believes that the previous missions were real and therefore that the photographs taken during those missions are authentic. These photos quash many of the objections based on photographs, such as the allegedly suspicious lack of stars, the fogging or melting of the film due to radiation or heat, and many of the technical objections: for example, deep space radiation and the Van Allen belts can't have been unsurmountable obstacles if Apollo 8 and 10 went safely through both on their way to the Moon. If he says that Apollo 8 and 10 weren't faked, then the whole argument that 1960s space technology wasn't up to the task of going to the Moon gets thrown out.

If instead his claim is that only the first Moon landing (Apollo 11) was faked to save face and meet Kennedy's end-of-the-decade deadline, but the subsequent ones were real, then the hoax theorist has to explain why the first landing had to be faked at great risk when the second one (Apollo 12, which, he argues, was real) took place *just four months later*, in November of 1969, still within the deadline.

And if he claims that the subsequent lunar missions were real, then the photographs, TV and movie footage shot during those later missions can be used as reference to disprove the allegations of anomalies in the Apollo visual record.

12.3.3 Can you explain in detail what you think really happened without contradicting yourself?

In the decades since the Moon landings, no conspiracy theorist has been able to provide a detailed and consistent alternative version of the events. Sooner or later, his description contradicts itself or requires entirely groundless, unproven assumptions. The only consistent, documented version of the events surrounding the Moon landings is the one presented by the overwhelming majority of historians and backed up by tons of technical evidence: we went to the Moon nine times and landed on it with crewed spacecraft six times.

A Moon hoax believer might argue that he doesn't have to provide a complete alternative version and that all he has to do is prove that the "official" version is false. Fine: but in all the decades since Apollo, conspiracy theorists have failed even to accomplish this simpler task and provide at least *one* item of irrefutable evidence of the alleged fakery.

Moreover, it's not true that hoax theorists don't offer alternative versions of the events: the claim that the "official" version is false *is* an alternative version. As such, it must not be self-contradicting, so ask the theorist for a detailed explanation of how he thinks things really happened and then wait for the contradictions to appear. Ask him to paint the full picture: it's the best way to find whether it makes any sense.

12.3.4 Were the Moon photographs faked or not?

For example, ask the hoax believer to consider the famous picture of Buzz Aldrin saluting the American flag on the Moon (Figure 12.3-1): was the flag added by photo editing or was it really there?

No matter how the conspiracy theorist replies, he's going to end up contradicting himself. If he answers that the photograph was faked by adding the flag, then this implies that it was actually taken on the Moon, otherwise it would have been easier to just put the flag on the movie set in the first place or, if the flag photo op had been somehow inexplicably forgotten, just go back to the movie set and take more pictures.



Figure 12.3-1. Aldrin salutes the US flag. NASA Photo AS11-40-5874.

If he claims that the flag was really there but the picture was shot in a studio, then ask why didn't they also fake a nice photograph of Neil Armstrong saluting the flag, while they were at it. After all, Armstrong was the commander of the mission and the first man to set foot on the Moon, yet there isn't a single decent picture of him on the lunar surface, and virtually all the Apollo 11 photos show Aldrin. How come?

12.3.5 How come not one of the 400,000 people who worked on the Apollo project has ever confessed to the hoax?

The Saturn V rocket and the Apollo spacecraft were designed and built by private contractors like Boeing and Grumman, not by some secretive NASA skunk works. If the claim is that the technology of the 1960s was not up to the job, then the conspiracy theorist has to explain why not one of the thousands of highly skilled workers and engineers who were part of the Apollo project has ever spilled the beans and why not one of the equally skilled testing crews ever noticed that the spacecraft was an unworkable dummy.

If the argument is that they realized what was going on but kept quiet to avoid repercussions, then the theorist must explain why there haven't been any deathbed confessions, anonymous leaks or at least some inadvertent disclosure by a blundering, disgruntled or drunken employee. Even the CIA, the NSA or the most ruthless organized crime syndicates can't achieve this level of absolute compliance. All it would take is one person of conscience like Chelsea Manning or Edward Snowden and the whole plot would be exposed.

If instead the hoax theorist claims that fully functional vehicles were built to fool the engineers and were launched to fool the public but weren't actually used to go to the Moon, that still leaves the problem of the other engineers who had to alter these vehicles to fake the flights: if there was no crew on board, for example, then someone had to design, test and install the extra hardware needed to pilot the spacecraft from Earth, land it on the Moon, send fake radio transmissions and data from the Moon to fool the radio astronomers on Earth (especially the Soviet ones), pick up Moon rocks, and so forth, and then keep perfectly quiet forever.

The fake rocket theory also contradicts the claim that the Apollo project was created and faked to divert its billions of dollars to covert government operations. Fake or not, lots of giant Saturn rockets still had to be seen lifting off from the pads in Florida, and giant rockets, plus all their supporting hardware and ground crews, don't come cheap, especially if they actually have to get to space. Then there would be the expense of faking the radio signals, shooting the fake Moon footage, manufacturing the Moon rocks, counterfeiting millions of pages of technical documents, paying everybody to keep quiet, and so on. Trying to fake the Moon landings probably would have been just as expensive as actually going to the Moon.

12.3.6 If human flight to the Moon is physically impossible, why did the Russians try so hard to do it?

Any Moon hoax theorist has to contend with the fact that the Soviet Union worked hard and secretly spent billions trying to put a cosmonaut on the Moon before the United States. This covert attempt, known as N1-L3, ran late due to technical problems and political squabbling and was abandoned when Neil Armstrong and Buzz Aldrin set foot on the Moon. The Russians also had a separate, simpler lunar fly-around project, named L1, which was almost ready but was canceled when Americans became the first to orbit around the Moon with Apollo 8.

True, the N1 rockets exploded four times out of four. But the fact that the Soviets took on this expensive challenge means that they, too, believed that it was technically possible to take human beings to the Moon and that all the natural obstacles, such as the Van Allen belts, deep space radiation or temperature extremes on the Moon, could be overcome.

12.3.7 How come the Soviets didn't realize the hoax and didn't expose it to the world?

The spies and the electronic eavesdropping outposts of the Soviet Union would have been quite capable of detecting any attempt at faking the flight trajectories and the radio and TV transmissions from the Moon. The Soviets had every reason to want to expose any fraud perpetrated by their enemy and humiliate the United States before the world. Yet they kept quiet and even congratulated America for the Moon landings. How come?

Some hoax theorists argue that the silence of the Soviets was bought by the United States, for example by giving them massive amounts of desperately needed grain, as mentioned and debunked in Chapter 10, or by threatening to reveal Russia's hidden space failures, such as the alleged deaths of the cosmonauts that preceded Yuri Gagarin, who according to this theory wasn't the first human being to fly in space but merely the first one to come back alive.

Of course, using one unproven conspiracy theory to justify another one isn't a very sound approach to finding out the truth (where's the evidence for these pre-Gagarin flights?). Moreover, history shows that during the Cold War the United States and Russia seldom had any qualms about exposing each other's atrocities and deceptions, so it seems rather unlikely that they somehow reached a gentleman's agreement about human spaceflight, which in the 1960s was a crucial aspect of political propaganda and prestige.

12.3.8 How many photographs and how many hours of live TV and movie footage would have had to be faked?

Ask the conspiracy theorist to give an estimate of the numbers involved in faking the photos and the footage of the Apollo missions. He probably will be quite far from the actual figures. You should point out that the photographs that were taken on the Moon and therefore allegedly would have to be faked are *over 6,500*. Just the TV and film footage shot on the lunar surface by the Apollo 16 mission amounts to *over fourteen hours*, and there were six Moon landings.

You should also point out that all this visual record would have to be faked without any of the errors in continuity or inconsistencies that occur regularly in movies and TV shows. And this fakery would have to be future-proof.

12.3.9 Using 1960s special effects, how did they prevent the film crew and equipment from being reflected in the astronauts' mirror-like visors?

Ask the Moon hoax proponent to explain in detail how this remarkable result could be achieved using only the non-digital visual effects available at the time of the Moon landings. Point out that the astronauts' visors often reflect quite clearly the details of the ground and of the nearby equipment and vehicles and therefore would have revealed any film crew and their bulky 1960s-era television and film cameras, especially in close-ups.

The only plausible way to conceal the crew and their equipment would have been not to use them at all: in other words, use only the still, TV or movie camera shown in the visor's reflection and have another astronaut-actor hold it, or mount it on a tripod or a replica of the Rover. But this would have entailed renouncing any extra equipment needed to create the special effects. These constraints would therefore make it even harder to achieve a credible level of fakery.

For example, the "cameraman" would have had to wear a spacesuit and the movie set would have had to include the so-called "fourth wall", the one behind the camera, and simulate the lunar sky and terrain through a full circle. All this would have to be achieved in a vacuum, with all the safety risks that this entailed, to obtain the correct swinging of the flag and the parabolic motion of the dust kicked up by the astronauts. All this leads to the next question.

12.3.10 Using 1960s special effects, how did they obtain the parabolic, swirl-free motion of the dust kicked up by the astronauts or by the Moon buggy?

This effect can only be obtained in a vacuum, so ask the conspiracy theorist for a technical description of how it would have been possible to achieve it without actually taking people and a buggy to the Moon and filming them there. Moreover, the behavior of the dust would have to be simulated while at the same time simulating the gait of the astronauts in one-sixth gravity.

Of course, no digital tricks would be allowed, because there was no broadcast-quality computer graphics in the 1960s. Ask the theorist for a practical demonstration or at least a detailed plan of how he would have done it.

12.3.11 How big was the set?

The Apollo TV footage includes long, unbroken sequences such as the one summarized in Figure 12.3-2 and taken from the Apollo 16 moonwalks. Note how the astronauts walk a great distance away from the camera without reaching the end of the alleged movie set. The boulder in the background turns out to be actually as big as a house. Ask the conspiracy theorist how this effect could be obtained on Earth.



Figure 12.3-2. Apollo 16: Young and Duke visit House Rock, which is 220 meters (720 feet) away from the TV camera and is behind the astronaut on the right in the first image. In the last image, the arrow indicates one of the helmets of the astronauts. These stills are taken from the live television broadcast of the moonwalk.

12.3.12 You see revealing mistakes everywhere: why would the fakery be so amateurish?

Ask the hoax theorist to explain why a conspiracy on which no less that the world reputation of the entire United States depended would have been entrusted to a bunch of bungling amateurs who made such egregious (alleged) mistakes as forgetting to add the stars or letting the flag flutter in the

nonexistent lunar wind. Then ask to explain how come not one of their supervisors and project managers noticed their blunders.

12.3.13 How come not one professional spaceflight expert agrees with you?

Are they all bribed or threatened into silence? How does this worldwide cover-up work, exactly? Does everyone who earns a degree in aerospace engineering or becomes an astronaut get a visit from the Men in Black, warning him or her not to talk about the Apollo fakery? And what happens to those who refuse to cooperate? Are they murdered? Are their brains zapped and stealthily reprogrammed?

Ask the conspiracy theorist how come all the alleged anomalies in the photographs, in the film and video recordings and in the technology of the Apollo project are seen as evidence of fakery only by people with no significant aerospace qualifications, while those who actually work in the field have no doubt whatsoever about the reality of the Moon landings.

Is it really believable that unskilled amateurs can find real anomalies that these experts have failed to notice and admit? And isn't it rather arrogant for a Moon hoax theorist to imply that by watching a few YouTube videos and looking at a few low-quality photos he or she can outsmart an astronaut or an aerospace engineer with years of practical experience?

12.3.14 Is there something or someone that would make you change your mind and accept that we did go to the Moon?

This question is extremely useful to tell apart doubters and hardcore conspiracy believers. A doubter will suggest someone he trusts or some factual observation or artifact that would dispel all doubt. This kind of evidence often already exists, but the doubter simply isn't aware of it.

A conspiracy believer will instead typically answer that there's nothing that would change his mind. This will be his undoing, because it shows that debating him is pointless: he has just admitted that his idea is not based on facts but is a narrow-minded prejudice, and that he has no intention of even listening to the facts.

13 Real secrets of the Moon landings

Moon hoax theories have a huge advantage over dry technical reports: they're great stories to tell. However, there's no need to make up absurd tales of conspiracy to bring out the excitement and wonder of an actual trip to the Moon.

Many details of the Apollo missions were not revealed or discussed publicly at the time of the flights because they were private, embarrassing or politically inappropriate. NASA was keen to project a squeaky-clean, flawlessly heroic image of its astronauts, and the press was somewhat complicit in this patriotic intent, so the unsavory or less uplifting aspects of Moon missions were left untold. This chapter is just a teaser of the some of these rarely shared stories.

13.1 Aldrin's pause on the LM ladder



Figure 13.1-1. Aldrin pauses on the ladder.

For decades, people who watched the live TV broadcast of the first moonwalk or studied its recordings were puzzled by Buzz Aldrin's long pause halfway down the ladder (Figure 13.1-1) before he joined Neil Armstrong on the surface of the Moon.

Was it dictated by fear? Was it a moment of disorientation caused by motion in an unconfined environment with unfamiliar one-sixth gravity? Was it an instant of spiritual contemplation of the amazing site? No such thing. Aldrin explained the true nature of this mysterious pause in the wonderful 2007 documentary *In the Shadow of the Moon* (Figure 13.1-2):



Figure 13.1-2. Aldrin reveals the surprising reason for his pause on the LM ladder [http://tiny.cc/03yfez].

> *We had it in our flight plan that we'd take the first 10-15 seconds down at the bottom of the ladder, sort of hold on to the edge of the landing gear and just sort of check our stability and so forth... So that's when I decided to take that period of time to, uh, to take care of a bodily*

function of slightly filling up the urine bag... so that I wouldn't be troubled with having to do that later on... Everybody has their firsts on the Moon, and that one hasn't been disputed by anybody.

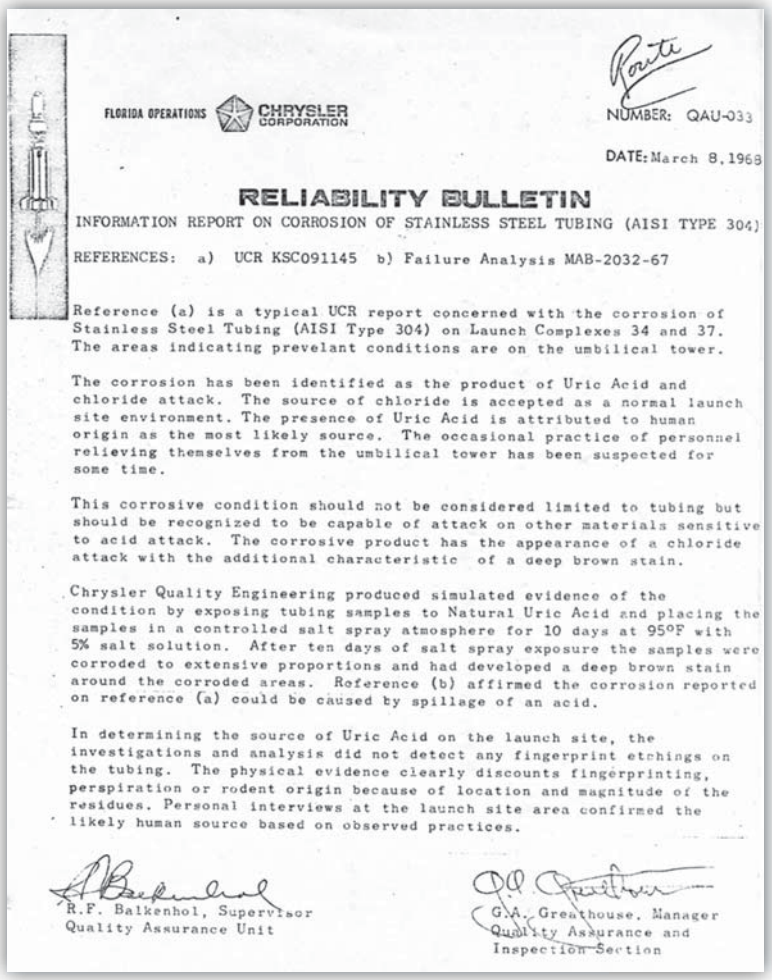
13.2 Suspicious pad corrosions and emissions

In a complex endeavor such as space launch, countless things can go wrong. Usually it's the unexpected problems that cause the greatest trouble.

For example, the *Reliability Bulletin* of March 8, 1968 (Figure 13.2-1) reported serious corrosion problems in the stainless steel pipes of pads 34 and 37 at the Kennedy Space Center.

The report revealed the cause of the corrosion: the combined effects of uric acid and chloride. While the chloride came from the launch site environment, the uric acid did not:

> *The occasional practice of personnel relieving themselves from the umbilical tower has been suspected for some time... Personal interviews at the launch site confirmed the likely human source based on observed practices.*



FLORIDA OPERATIONS CHRYSLER CORPORATION

NUMBER: QAU-033

DATE: March 8, 1968

RELIABILITY BULLETIN

INFORMATION REPORT ON CORROSION OF STAINLESS STEEL TUBING (AISI TYPE 304)

REFERENCES: a) UCR KSC091145 b) Failure Analysis MAB-2032-67

Reference (a) is a typical UCR report concerned with the corrosion of Stainless Steel Tubing (AISI Type 304) on Launch Complexes 34 and 37. The areas indicating prevelant conditions are on the umbilical tower.

The corrosion has been identified as the product of Uric Acid and chloride attack. The source of chloride is accepted as a normal launch site environment. The presence of Uric Acid is attributed to human origin as the most likely source. The occasional practice of personnel relieving themselves from the umbilical tower has been suspected for some time.

This corrosive condition should not be considered limited to tubing but should be recognized to be capable of attack on other materials sensitive to acid attack. The corrosive product has the appearance of a chloride attack with the additional characteristic of a deep brown stain.

Chrysler Quality Engineering produced simulated evidence of the condition by exposing tubing samples to Natural Uric Acid and placing the samples in a controlled salt spray atmosphere for 10 days at 95°F with 5% salt solution. After ten days of salt spray exposure the samples were corroded to extensive proportions and had developed a deep brown stain around the corroded areas. Reference (b) affirmed the corrosion reported on reference (a) could be caused by spillage of an acid.

In determining the source of Uric Acid on the launch site, the investigations and analysis did not detect any fingerprint etchings on the tubing. The physical evidence clearly discounts fingerprinting, perspiration or rodent origin because of location and magnitude of the residues. Personal interviews at the launch site area confirmed the likely human source based on observed practices.

R.F. Balkenhol, Supervisor
Quality Assurance Unit

G.A. Greathouse, Manager
Quality Assurance and
Inspection Section

Figure 13.2-1. The pipe corrosion report reveals an unexpected source of acid.

In another somewhat similar case, reported in *Memorable Moments - My Years with the Apollo Program* by John T. Everett, the hydrogen leak detector of the launch tower was triggered, causing the activation of the water sprinkler safety system, which led to several million dollars' worth of damage. It later emerged that the highly sensitive detector had reacted to the *"gaseous emissions of* [a] *robust engineer"* from Chrysler who was changing a component in the vicinity.

13.3 Smuggling on the Moon: the Sieger covers

Scott, Worden and Irwin, the crew of the Apollo 15 flight (Figure 13.3-1), secretly took to the Moon, in one of Scott's spacesuit pockets, 398 postmarked envelopes in addition to the 243 authorized by NASA for commemorative philatelical purposes.

They did this on behalf of H. Walter Eiermann, who in turn was working for a German stamp collector, Hermann Sieger. The agreement was that one hundred of these undeclared envelopes (known as *covers* by collectors) would be sold by the astronauts to Eiermann for 7,000 dollars, deposited on a foreign account for each astronaut, while the other 298 would be kept by the crew as souvenirs. The agreement also included the provision that the Eiermann/Sieger covers would not be sold until the Apollo program was over.

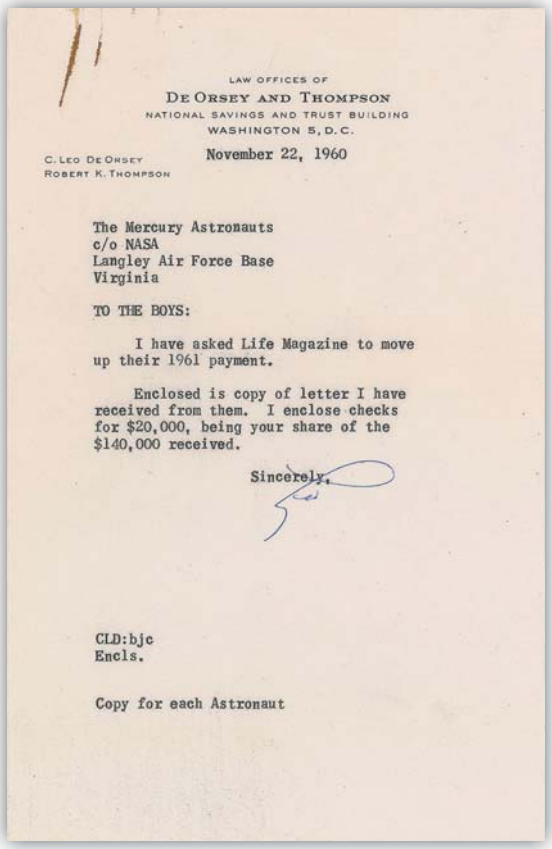


Figure 13.3-1. David Scott, Alfred Worden and James Irwin with the subsatellite that they placed in lunar orbit during Apollo 15. NASA photo AP15-S71-22401.



Figure 13.3-2. A picture of one of the envelopes taken to the Moon by Apollo 15. Credit: Wikimedia.

Eiermann, however, sold his covers to Sieger, who put them on public sale shortly after the Apollo 15 flight. This led to a public scandal and a congressional inquiry that also involved Jack Swigert (Apollo 13), as financial gain from the flights by the Apollo crews was not permitted. The Apollo 15 crew returned their 7,000 dollars, but Swigert, Scott and Worden were removed from service as astronauts and Irwin left NASA to start religious preaching.



LAW OFFICES OF
DE ORSEY AND THOMPSON
NATIONAL SAVINGS AND TRUST BUILDING
WASHINGTON 5, D.C.

C. LEO DE ORSEY
ROBERT K. THOMPSON

November 22, 1960

The Mercury Astronauts
c/o NASA
Langley Air Force Base
Virginia

TO THE BOYS:

I have asked Life Magazine to move up their 1961 payment.

Enclosed is copy of letter I have received from them. I enclose checks for $20,000, being your share of the $140,000 received.

Sincerely,

CLD:bjc
Encls.

Copy for each Astronaut

Figure 13.3-3. A letter from the DeOrsey and Thompson law office, giving the first installment from Life Magazine to the seven Mercury astronauts in 1960. Credit: Icollector.

It should be noted that NASA wrote rules regarding what astronauts could take with them to space, and made it clear that flown items could not be sold but only donated, only after this incident.

These rules were strikingly different from the treatment reserved for Mercury astronauts, who were allowed to share a 500,000-dollar contract for exclusive coverage by the *Time-Life* magazine group.

Moreover, although it is commonly believed that Apollo astronauts were generously paid for their spaceflights, in actual fact they only received standard military salaries. Accordingly, they often tried to provide some kind of financial security to their families in case of death, for example by signing items which would be auctioned off to collectors by their spouses. If they survived, they could receive consulting fees, be paid for public appearances or sell their autobiographies, but only after retiring from active service.

13.4 Secretive commemorations

Near the end of their historical moonwalk, while Neil Armstrong was still on the lunar surface and Buzz Aldrin had already reentered the LM, the two astronauts had a rather cryptic exchange of words over the open radio channel. Armstrong asked Aldrin, *"How about that package out of your sleeve? Get that?"*

"No," answered Aldrin tersely. *"OK, I'll get it when I get up there,"* Armstrong replied. After a brief pause, Aldrin asked *"Want it now?"* and Armstrong answered *"Guess so".* Another pause and then Armstrong asked *"OK?"* and Aldrin answered *"OK".* Nothing more was said about the *"package"*.



Figure 13.4-1. From 15:21 onward, the live TV broadcast of the exchange between Aldrin and Armstrong [http://tiny.cc/t3t7iz].

The conversation can be heard in the TV broadcast of the moonwalk, for example at 15:21 from the beginning of this video taken from the documentary *Moonscape*.

Armstrong and Aldrin were referring guardedly to a set of commemorative items to be left on the Moon:

- an Apollo 1 patch, in honor of Gus Grissom, Ed White and Roger Chaffee, who had died in a fire in their spacecraft during a preflight test;
- an olive branch sculpted in gold, identical to those that the two Apollo 11 moonwalkers had taken to the Moon for their wives and for Michael Collins' wife (Figure 13.4-2);
- and a small silicon disk that contained written messages from several heads of state from all over the world and other data.



Figure 13.4-2. A gold olive branch similar to the one left on the Moon by the Apollo 11 crew. Detail of NASA photo S69-40941.

This was the official content list of the package, as reported in NASA press release 69-83F on July 13, 1969. But there were also other politically very sensitive items: two Soviet medals, one in honor of cosmonaut Vladimir Komarov, who had died at the end of his Soyuz 1 flight due to parachute failure, and one for Yuri Gagarin, the first man to orbit the Earth, who had perished in a plane crash in 1968.

This was a gesture of chivalry among spacefarers that at the time of the Cold War, when the Soviet Union was seen as a deadly enemy, might not have been appreciated by many and therefore was kept confidential during the global television broadcast, although it was

not held strictly secret, as it was mentioned in a public statement by then president Nixon on the day of the Apollo 11 liftoff from Earth.[1]

This gesture was followed by another discreet international tribute during Apollo 15, which left on the Moon a plaque dedicated to the American and Russian astronauts who were known to have died (Bassett, Belyayev, Chaffee, Dobrovolsky, Freeman, Gagarin, Givens, Grissom, Komarov, Patsayev, See, Volkov, White and Williams) and a small statue, the *Fallen Astronaut* (Figures 13.4-3 and 13.4-4).

1 *Statement about Honoring American and Russian Space Heroes During the Apollo 11 Mission, July 17, 1969*, also published in *Public Papers of the Presidents of the United States: Richard M. Nixon, 1969*, United States Government Printing office (1971).



The statue and the plaque were taken secretly to the Moon by David Scott and were placed on the lunar surface, without mentioning them on the radio, at the end of the last moonwalk of the mission. Their presence was disclosed only when the Apollo 15 astronauts returned to Earth.

On the left: Figure 13.4-3. The Fallen Astronaut *sculpture and the commemorative plaque, placed and photographed on the Moon by the Apollo 15 astronauts.*

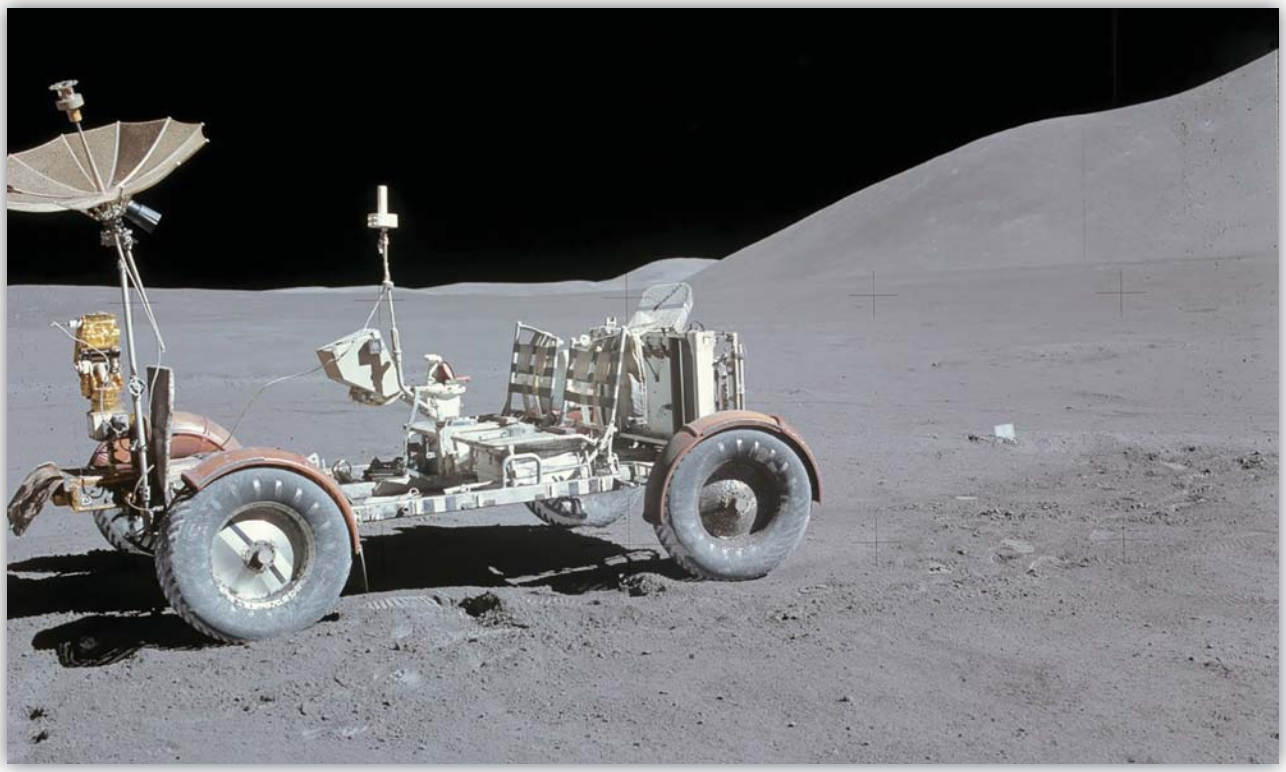


Figure 13.4-4. The Fallen Astronaut *can be seen to the right of the Lunar Rover, which is in its final parking place. NASA photo AS15-88-11902 (cropped).*

13.5 Naked women on the Moon

In November 1969, Apollo 12's Alan Bean and Charles "Pete" Conrad landed on the Moon while Richard Gordon remained in lunar orbit. It became clear immediately that this was not going to be a solemn expedition. Conrad's first remark as he stepped off the ladder of the LM set the tone by referencing humorously Neil Armstrong's timeless words: *"Man, that may have been a small one for Neil, but that's a long one for me!"* Conrad was referring both to his own short stature and to a bet made with Italian journalist Oriana Fallaci to prove to her that the astronauts' words were not scripted by NASA.

But roughly two and a half hours into their moonwalk, things took a strange turn: the two astronauts began giggling so much that there was some concern that their oxygen supply might be malfunctioning or that they had been affected by some mysterious space sickness.

Conrad explained the somewhat alarming laughter in the December 1994 issue of *Playboy*. The two lunar astronauts had a so-called *cuff checklist* (basically a small ring binder with laminated fireproof sheets, strapped to their left sleeve) as a reminder of the procedures to be performed. It was a simple and effective solution.

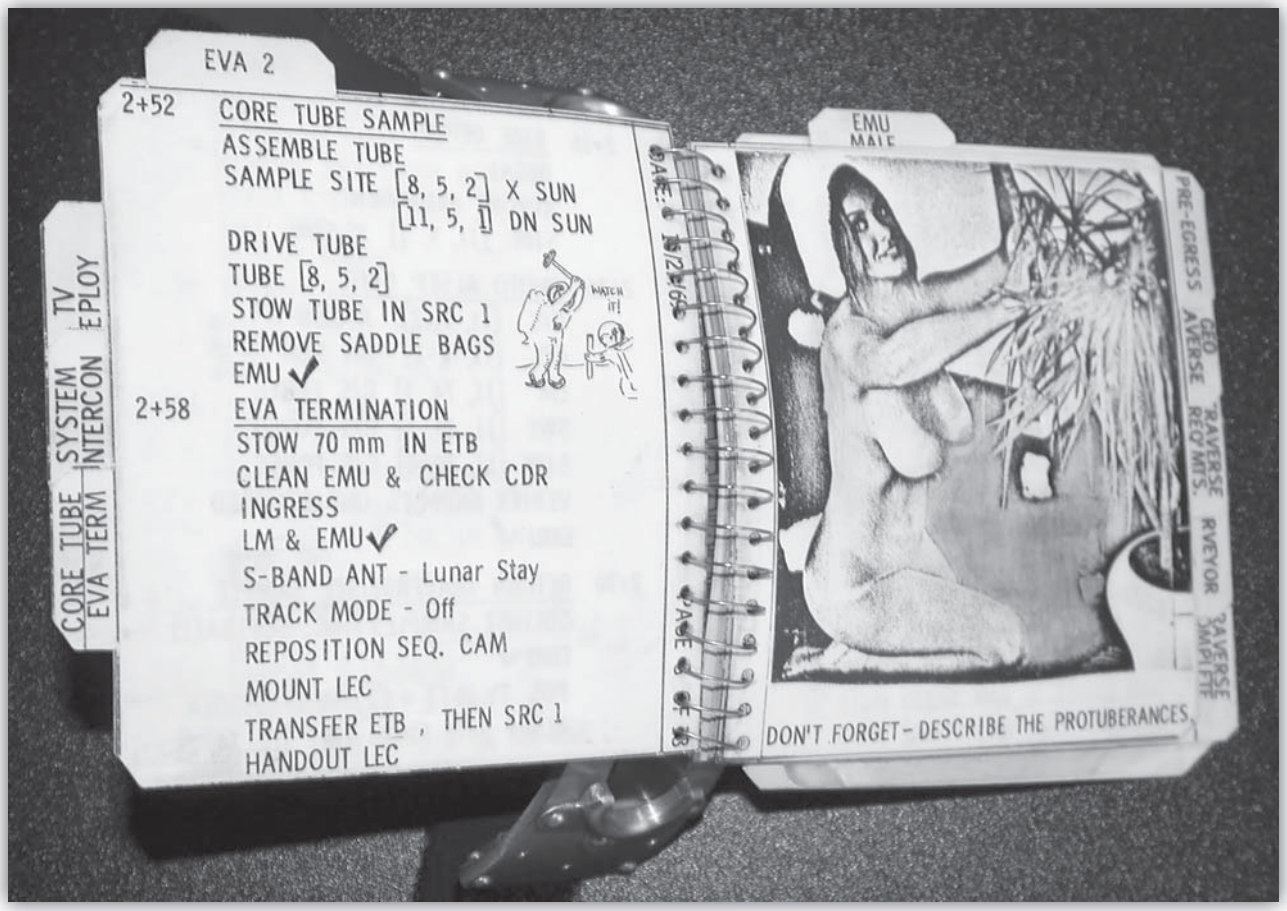
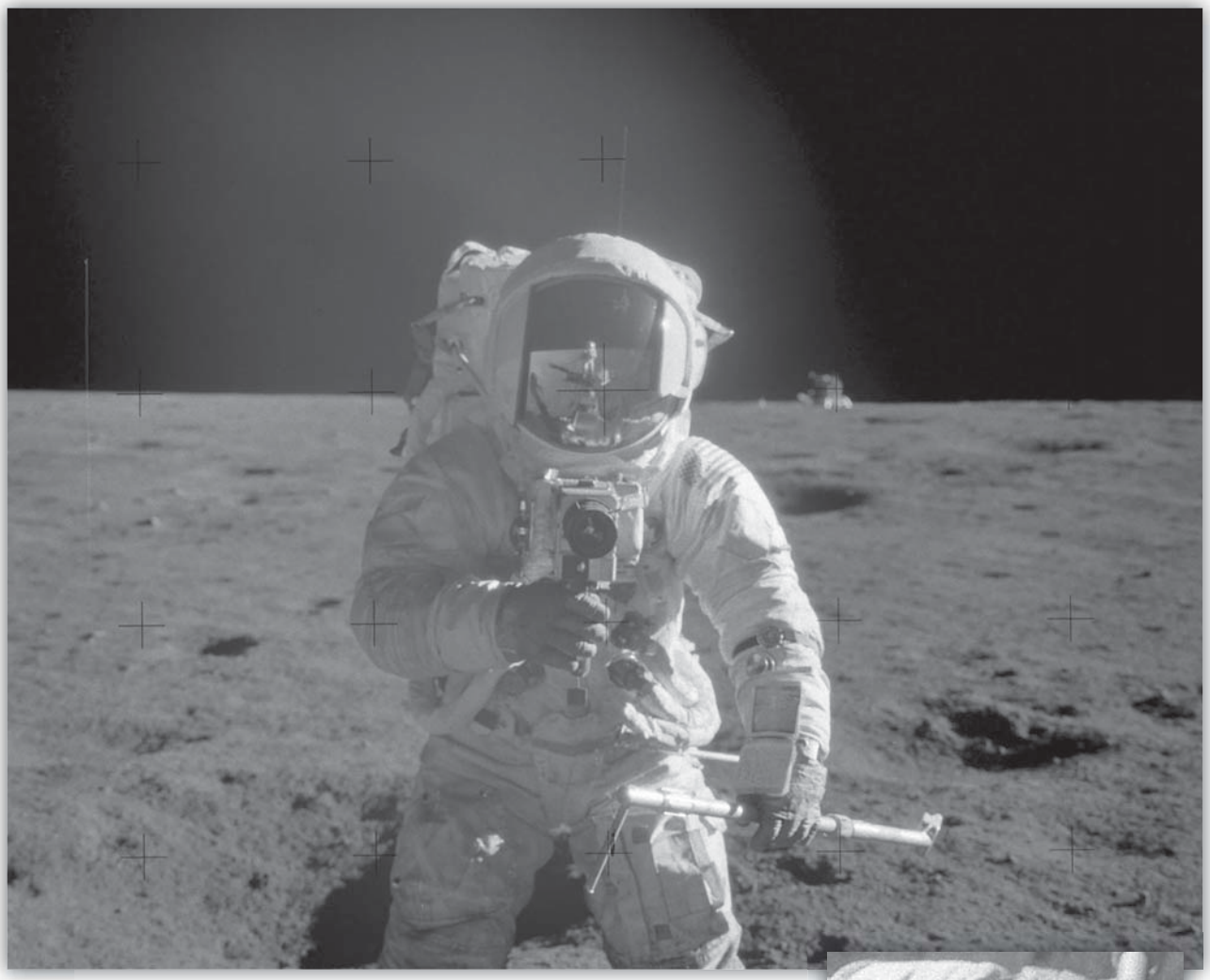


Figure 13.5-1. Alan Bean's cuff checklist, with Playmate Cynthia Myers, Miss December 1968.

However, Dave Scott and Jim Irwin, members of the mission's backup crew, had arranged a prank: they had inserted Playmate photographs, carefully photocopied onto fireproof paper, among the pages of the cuff checklists, adding captions full of *double entendres*.

Conrad found Miss September 1967, Angela Dorian, with the caption *"Seen any interesting hills & valleys?"*, and Miss October 1967, Reagan Wilson (*"Preferred tether partner"*); Bean found Miss December 1968, Cynthia Myers (*"Don't forget – describe the protuberances"*, Figure 13.5-1), and Miss January 1969, Leslie Bianchini (*"Survey - Her activity"*).

Richard Gordon, in the Command Module orbiting the Moon, also found a Playmate hidden on board, in the form of the current month's *Playboy* calendar page, featuring DeDe Lind (formerly Miss August 1967), which had been fixed with Velcro inside one of the Command Module's cabinet doors.



Above: Figure 13.5-2. Pete Conrad on the Moon. His cuff checklist is open on the page with Reagan Wilson, Miss October 1967. NASA photo AS12-48-7071 (cropped).



On the right: Figure 13.5-3. Detail of AS12-48-7071, showing the cuff checklist. The left page shows Reagan Wilson.

This is not a legend or a colorful anecdote concocted by an astronaut as a prank: the Playmate pictures from the cuff checklist are on NASA's website and the calendar page provided to Gordon was auctioned among the Apollo 12 memorabilia in January 2011.[2]

2 *Apollo 12 Playboy Stowaway to be Auctioned*, by Ian O'Neill, *Discovery News*, January 11, 2011.

While this might be seen as just a curious case of nudity on NASA's usually very prudish website and as the first documented instance of erotica taken to another world, it also shows that despite the hype and heroic rhetoric that often surrounds them, astronauts are, after all, very human beings, with the same urges and weaknesses as the rest of us.

And this is what makes their accomplishments so great.

13.6 The President's speech in case of Moon disaster

In 1999 it was disclosed that famed journalist and presidential speechwriter William Safire had drafted a message that then President Nixon would have read to the nation if Armstrong and Aldrin had been stranded on the Moon with no way to get home.

H. R. Haldeman was the Chief of Staff of the White House at the time.

To: H.R. Haldeman
from: Bill Safire
July 18, 1969

IN EVENT OF MOON DISASTER:

Fate has ordained that the men who went to the moon to explore in peace will stay on the moon to rest in peace.

These brave men, Neil Armstrong and Edwin Aldrin, know that there is no hope for their recovery. But they also know that there is hope for mankind in their sacrifice.

These two men are laying down their lives in mankind's most noble goal: the search for truth and understanding.

They will be mourned by their families and friends; they will be mourned by the nation; they will be mourned by the people of the world; they will be mourned by a Mother Earth that dared send two of her sons into the unknown.

In their exploration, they stirred the people of the world to feel as one; in their sacrifice, they bind more tightly the brotherhood of man.

In ancient days, men looked at the stars and saw their heroes in the constellations. In modern times, we do much the same, but our heroes are epic men of flesh and blood.

Others will follow, and surely find their way home. Man's search will not be denied. But these men were the first, and they will remain the foremost in our hearts.

For every human being who looks up at the moon in the nights to come will know that there is some

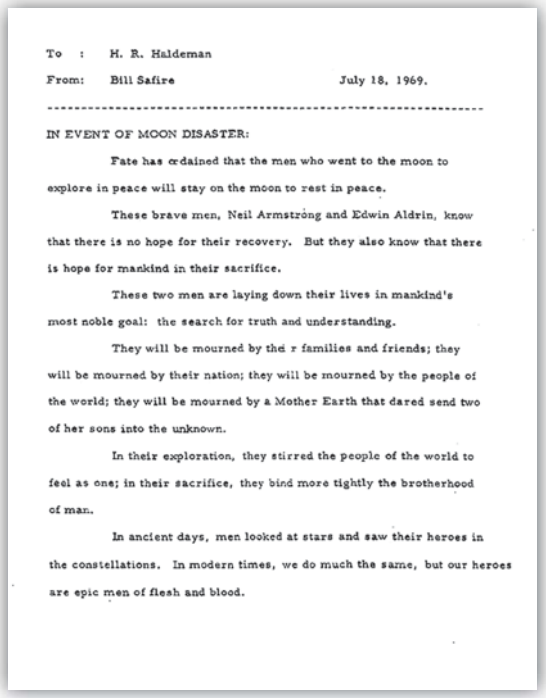
corner of another world that is forever mankind.

PRIOR TO THE PRESIDENT'S STATEMENT:

The President should telephone each of the widows-to-be.

AFTER THE PRESIDENT'S STATEMENT, AT THE POINT WHEN NASA ENDS COMMUNICATIONS WITH THE MEN:

A clergyman should adopt the same procedure as a burial at sea, commending their souls to "the deepest of the deep," concluding with the Lord's Prayer.



To : H. R. Haldeman

From: Bill Safire July 18, 1969.

IN EVENT OF MOON DISASTER:

Fate has ordained that the men who went to the moon to explore in peace will stay on the moon to rest in peace.

These brave men, Neil Armstrong and Edwin Aldrin, know that there is no hope for their recovery. But they also know that there is hope for mankind in their sacrifice.

These two men are laying down their lives in mankind's most noble goal: the search for truth and understanding.

They will be mourned by their families and friends; they will be mourned by their nation; they will be mourned by the people of the world; they will be mourned by a Mother Earth that dared send two of her sons into the unknown.

In their exploration, they stirred the people of the world to feel as one; in their sacrifice, they bind more tightly the brotherhood of man.

In ancient days, men looked at stars and saw their heroes in the constellations. In modern times, we do much the same, but our heroes are epic men of flesh and blood.

Figure 13.6-1. The first page of the message prepared in case of failure of the Apollo 11 mission.

14 Remembering the fallen

Many men and women have lost their lives during spaceflight and for this reason have been commemorated by the media and by the general public. However, there are also many people who were selected as astronauts or cosmonauts and worked on these missions but died before reaching space. Their sacrifice and their contributions are often neglected, and the fate of one of them was made public only several years later, when the secrets of the Soviet space program were exposed.

The *In memoriam* section of the preface to this book listed the names of these fallen spacefarers; here is some information about them, as a supplement to the details already given in this book for some of these brave men and women.

14.1 Michael James Adams

A USAF major and test pilot, Adams was selected as an astronaut for the MOL (*Manned Orbiting Laboratory*) military project, which was intended to provide crewed space stations to be used for monitoring and reconnaissance of the territory of potential enemies.



Figure 14.1-1. Michael J. Adams next to an X-15 experimental aircraft, 22 March 1967. Source: NASA.

The MOL project was canceled before any actual launches were made, but Adams still flew into space when he piloted the X-15 experimental hypersonic rocket plane and reached an altitude of 81 kilometers (266,000 feet) on November 15, 1967. This qualified him as an astronaut according to USAF criteria.

This flight, however, was fatal: a malfunction of the electrical systems of the X-15 and an initial disorientation

caused the spacecraft to assume an incorrect attitude, which induced a spin at Mach 5 (five times the speed of sound). The stresses overwhelmed the airframe, which broke up, killing Adams. He was the only fatality of the highly experimental X-15 program, which included Neil Armstrong among its pilots. Many of the records set with the X-15 are still unbeaten.

Mike Adams was posthumously awarded Astronaut Wings and in 1991 his name was added to the Astronaut Memorial at the Kennedy Space Center in Florida.

14.2 Michael P. Anderson, David M. Brown, Kalpana Chawla, Laurel B. Clark, Rick D. Husband, William C. McCool and Ilan Ramon

The seven members of the crew of Space Shuttle *Columbia* died on February 1, 2003 during reentry. At liftoff, a fragment of the thermal insulation of the Shuttle's external tank had struck and damaged the thermal protection of the leading edge of the spacecraft's wing. The red-hot air that formed around the spacecraft during reentry penetrated the wing and partially melted its internal structure, which broke up catastrophically as *Columbia* was flying at 15 times the speed of sound at an altitude of approximately 55 kilometers (181,000 feet), killing the entire crew instantly.



Figure 14.2-1. A photograph of the Columbia *crew in space, recovered from the debris of the spacecraft. Top, from the left: David Brown, William McCool and Michael Anderson. Bottom, from the left: Kalpana Chawla, Rick Husband, Laurel Clark and Ilan Ramon.*

14.3 Charles Arthur Bassett II and Elliot McKay See, Jr.

Charles Bassett II was a USAF captain, test pilot and member of the third group of astronauts chosen by NASA in October 1963; Elliot See was a US Navy engineer and test pilot and member of the second group of astronauts, selected in September 1962, in addition to being in charge of supervising the design and development of guidance and navigation systems for US spacecraft.

Bassett and See were assigned to the Gemini 8 mission, but on February 28, 1966 they died in the crash of their T-38 training jet as they attempted an instrument landing in low visibility conditions. Bassett was 34 years old; See was 38.



Figure 14.3-1. Elliott See (left) and Charles Bassett (right).

14.4 Valentin Bondarenko

Lieutenant Valentin Bondarenko was a fighter pilot in the Soviet air force. On April 28, 1960 he was selected for the first group of 29 cosmonauts and on May 31st of the same year he began training to fly the Vostok 1, the same spacecraft on which Yuri Gagarin would perform the first crewed orbital flight in the history of mankind.

On March 23, 1961, at the end of the third day of a two-week experiment in a pressure chamber at the Institute for Biomedical Studies in Moscow, Bondarenko removed from his body the sensors that monitored his vital functions and cleaned himself with a wad of cotton impregnated with alcohol. He tossed the cotton, which fell onto an electric heater and caught fire, igniting the cosmonaut's woolen clothing. In the pure oxygen environment of the chamber, the flames raged uncontrollably, with devastating results.



Figure 14.4-1. Valentin Bondarenko (right), with his wife Anya and their child Alexandre in 1956. Source: Anecdotes-spatiales.

It took half an hour to open the door of the chamber. By then, Bondarenko had suffered third-degree burns on all of his body except for his feet, partly protected by his flight boots. He died in hospital after 16 hours of agony at the age of 24. According to some historical sources, the man assigned to stand by him and report his condition was Yuri Gagarin. Three weeks later, Gagarin flew in space and into the history books, presumably as a replacement for Valentin Bondarenko.

The Praesidium of the Supreme Soviet awarded Bondarenko the Order of the Red Star on June 17, 1961 and the Soviet defense minister issued secret orders that his family be *"given all that is necessary, as befits the family of a cosmonaut"*.

The horrible death of the young pilot was kept secret until 1980. His face was deleted from the official Soviet photographs of the first six cosmonauts. Cosmonaut Alexei Leonov, questioned about the censorship of these photos and the rumors of cosmonauts who had died in secret, lied repeatedly to Western journalists. Bondarenko's death was revealed in Russia only in 1986, twenty-seven years later, by an article penned by Yaroslav Golovanov on *Izvestia*. No Soviet vehicle ever used a pure-oxygen atmosphere. A crater on the far side of the Moon bears his name.

14.5 Roger B. Chaffee, Virgil I. "Gus" Grissom and Ed H. White

On January 27, 1967, Grissom, White and Chaffee, astronauts of the Apollo space program, were on the launch pad, inside their Apollo 1 spacecraft, for a routine static systems test to prepare for their spaceflight when fire broke out in the cabin. The pure-oxygen environment at atmospheric pressure turned the fire instantaneously into an inferno, which killed the three astronauts in less than thirty seconds. The sudden cabin pressure increase jammed the hatch, which opened inward, blocking any attempt at escape and rescue.

The tragedy had an enormous impact on public opinion in the United States and forced NASA to rethink drastically its procedures and improve the redesign of the Apollo spacecraft that was already in progress, introducing for example a hatch that could be opened easily and outward, removing most of the flammable components and using a mixed nitrogen and oxygen atmosphere for the launch phase. These modifications made the Apollo spacecraft much safer and more reliable than they were initially. In a way, the success of the lunar missions is a direct consequence of the sacrifice of Grissom, White and Chaffee.



Figure 14.5-1. Left to right: Gus Grissom, Ed White and Roger Chaffee.

14.6 Georgi Dobrovolski, Viktor Patsayev and Vladislav Volkov

These three Soviet cosmonauts had completed successfully the first visit to Salyut 1, the first space station in the history of spaceflight, and were beginning their maneuvers for reentry on June 30, 1971, when the cabin of their Soyuz 11 spacecraft depressurized in a few seconds due to a damaged valve at an altitude of 168 kilometers (551,000 feet).

The valve was out of reach and the cosmonauts were not wearing pressure suits due to the tightness of the cabin and therefore died by suffocation. Dobrovolski was 43; Patsayev was 38; Volkov was 35. Their ashes are in the Kremlin, in Moscow.



Figure 14.6-1. Patsayev, Dobrovolsky and Volkov in the Soyuz simulator during training.

14.7 Theodore Cordy Freeman

A USAF captain, aeronautical engineer and test pilot of experimental aircraft, Freeman was a member of the third group of astronauts selected by NASA in October 1963. He died on October 31, 1964, when the windshield of the T-38 aircraft he was piloting was struck by a goose and windshield fragments were ingested by the engines; Freeman ejected, but his altitude was insufficient and his parachute didn't have time to open. He was 34 years old. Freeman was the first designated US astronaut to die during the space program.



Figure 14.7-1. Theodore (Ted) Freeman.

14.8 Edward Galen Givens, Jr.

A USAF major and test pilot, Givens was selected in April 1966 for the fifth group of astronauts, composed of 19 men. He completed his astronaut training and was assigned to the backup crew of Apollo 7.

His group was intended to provide the astronaut pilots for the Apollo Applications Program, which at the time was intended as a series of ten Moon landings and thirty flights to space stations in Earth orbit. Almost all the other members of this group went to space on Apollo, Skylab or Shuttle flights, but Ed Givens died in a car accident on June 6, 1967. He was 37 years old.



Figure 14.8-1. Ed Givens. NASA photo S66-34846, 25 May 1966.

14.9 Gregory Jarvis, Christa McAuliffe, Ronald McNair, Ellison Onizuka, Judith Resnick, Francis "Dick" Scobee and Michael J. Smith

The entire crew of Space Shuttle *Challenger* died during liftoff on January 28, 1986.

One minute and thirteen seconds after their spacecraft had left the launch pad, one of the gaskets of the lateral solid-propellant boosters broke due to the intense cold that it had experienced overnight on the pad, allowing a tongue of flame to strike the external tank, full of liquid oxygen and hydrogen. The tank ruptured and its fuel ignited catastrophically while the Shuttle was at an altitude of approximately 15 kilometers (48,000 feet) and America was watching helplessly as the tragedy was broadcast live on national television.

The aerodynamic stresses broke up the Shuttle, but the cabin remained almost intact, protecting the astronauts (who had no usable means of escape) until impact occurred in the ocean at over 330 kilometers per hour (200 mph).

The *Challenger* disaster was the first loss of a US crew during spaceflight.



Figure 14.9-1. Left to right, front row: Michael J. Smith, Francis R. (Dick) Scobee and Ronald E. McNair. Left to right, back row: Ellison Onizuka, Christa McAuliffe, Gregory Jarvis and Judith Resnik.

14.10 Vladimir Komarov

Komarov's Soyuz 1 spacecraft departed from the Baikonur cosmodrome on April 23, 1967, and showed problems right after the climb to space. One of its solar panels failed to open, leading to a shortage of onboard power and making attitude corrections difficult. After thirteen orbits, the automatic stabilization system had failed completely and the manual one was only partially functional.

The decision was taken to abort the mission, and five orbits later the spacecraft began reentry. The drogue parachute open properly, but the main chute did not, due to a faulty pressure sensor. Komarov opened the spare parachute, which caught in the drogue chute that had not been jettisoned. The spacecraft was slowed only partially and struck the ground at approximately 140 kilometers per hour (90 mph), killing Komarov instantly.



Figure 14.10-1. Vladimir Komarov.

14.11 Robert H. Lawrence, Jr.

A USAF major and test pilot, Robert Lawrence was chosen in June 1967 for the third group of US Air Force astronauts that were intended to fly in space as part of the MOL military space station project. He thus became the first African-American designated astronaut.

He provided important contributions to the space program, as his test flights with modified aircraft were fundamental in developing the steep, unpowered glide paths that would be used by the Space Shuttle.

Lawrence, however, never flew in space. He died on December 8, 1967, in the crash of the F-104 supersonic trainer piloted by his trainee pilot as he was teaching him to perform a so-called "flare", one of the experimental landing maneuvers used by the spaceplanes of the period, such as the X-15, and developed and mastered by Lawrence. He was 31.

His name is on the Space Mirror Memorial at the Kennedy Space Center but is not among those left on the Moon on a commemorative plaque placed by the Apollo 15 astronauts in 1971. One of the reasons is that the Pentagon uses the "astronaut" designation only for those who have flown to an altitude of 80 kilometers (50 miles) or more; being merely selected does not qualify. His mission patch was taken to space by the Shuttle *Atlantis* during the STS-86 flight.



Figure 14.11-1. Robert Henry Lawrence. Source: Hill Air Force Base.

14.12 Clifton Curtis Williams, Jr.

A major of the US Marines and a test pilot, Williams was selected for NASA's third astronaut group in October 1963 and was assigned to the backup crews of Gemini 10 and Apollo 9.

He died on October 5, 1967, at the age of 35, when a mechanical failure of his T-38 supersonic trainer rendered the controls unusable and the plane entered an uncontrolled roll. Williams ejected, but he was flying too low and too fast for the ejector seat to work.

The Apollo 12 mission commemorated his loss with a patch bearing four stars (one for each of the astronauts who flew, plus one for Williams). Alan Bean, who had been his commander in the backup crew of Gemini 10, placed Williams' astronaut wings pin on the Moon.



Figure 14.12-1. Official photograph of Clifton C. Williams, S64-31711, 1964 (NASA).

15 References

Due to legibility constraints, it has not been possible to indicate explicitly the technical source of each fact reported in the preceding chapters. However, I have carefully kept track of all the sources in my notes, so if you need to know where I found a specific item of information, just e-mail me at *paolo.attivissimo@gmail.com*.

The main reference sources are listed in the following pages and are also useful as further reading on the subject. Many are available directly on the Internet: for the sake of brevity, I have not included links to all of them.

15.1 Public photo archives

Apollo Archive
apolloarchive.com
Photographs, timelines, schematics, simulators and many other documents.

Apollo Image Archive
wms.lroc.asu.edu/apollo/browse
High-resolution, direct scans of the original Apollo films used by the Panoramic Camera, Mapping (Metric) Camera, Apollo Lunar Surface Closeup Camera (ALSCC) and Nikon 35 mm camera. Direct scans of the other films are at the *March to the Moon* website.

Apollo Image Atlas (70 mm)
www.lpi.usra.edu/resources/apollo/catalog/70mm/
Archive of the Apollo photographs taken on 70 mm film.

Apollo Image Atlas (35 mm Nikon)
www.lpi.usra.edu/resources/apollo/catalog/35mm/
Photographs taken on 35 mm film during the Apollo 17 flight.

Apollo Image Atlas (Metric Camera)
www.lpi.usra.edu/resources/apollo/catalog/metric/
Photos from the automatic lunar surface mapping camera installed in the service module of Apollo 15, 16 and 17.

Apollo Image Atlas (Panoramic Camera)
www.lpi.usra.edu/resources/apollo/catalog/pan/
Photographs from the automatic panoramic lunar surface mapping camera installed in the service module of Apollo 15, 16 and 17.

Apollo Lunar Surface Closeup Camera (ALSCC)
www.lpi.usra.edu/resources/apollo/catalog/alscc/
Catalog of the stereo images of lunar soil taken by the closeup camera during the Apollo missions.

Gateway to Astronaut Photography of Earth
eol.jsc.nasa.gov
Despite the name, this site includes very high-resolution scans of the Apollo mission photographs, including the photos taken on the Moon.

LIFE Magazine
images.google.com/images?q=Apollo+source%3Alife
Pictures of the Apollo program taken from the well-known US magazine.

Lunar Orbiter Photo Gallery
www.lpi.usra.edu/resources/lunarorbiter
Collection of the lunar mapping images taken by the Lunar Orbiter automatic probes launched by the United States (1966-67).

Lunar Orbiter Photographic Atlas of the Moon
www.lpi.usra.edu/resources/lunar_orbiter
Lunar atlas based on the photographs taken by the Lunar Orbiter probes.

Lunar Panoramas
spacemodels.nuxit.net/Panoramas/index.htm
Panoramas created by merging digitally the original Apollo photographs taken on the Moon.

March to the Moon
tothemoon.ser.asu.edu/gallery/apollo
High-resolution, direct scans of the original films used in the Hasselblad, ALSCC and Nikon cameras of all the Apollo missions, including Apollo 4 and Apollo 6.

NASA Images
www.nasaimages.org
An immense catalog of photographs from all aspects of the US space program.

NIX - NASA Image Exchange
nix.nasa.gov
One of NASA's primary audio, photo and video archives.

Ranger Photographs of the Moon
www.lpi.usra.edu/resources/ranger
Lunar photographs taken by the United States' Ranger probes (1961-65).

Science Photo
www.sciencephoto.com
Commercial catalog of science photographs, including images from the space programs of several countries.

15.2 Technical reference sites

Apollo 11 Onboard Audio
www.nasa.gov/mission_pages/apollo/40th/apollo11_audio.html
Recordings and transcripts of the onboard conversations during the Apollo 11 flight.

Apollo Artifacts
www.apolloartifacts.com
Vast private collection of Apollo spaceflight-related items.

Apollo Bibliography
history.nasa.gov/alsj/apollo.biblio.html
Photographs, documents, software, models, reference books and sites.

Apollo Flight Journal
history.nasa.gov/afj/
Highly detailed and richly commented timeline of the Apollo flights, including transcripts of all the radio communications and onboard conversations.

Apollo Lunar Surface Journal
www.hq.nasa.gov/alsj
A full timeline of the lunar excursions, with commented transcripts of every word, photograph and action of the moonwalkers.

Apollo Saturn Reference Page
www.apollosaturn.com
Technical documents related to the Saturn V booster.

Apollo Technical Data Library
www.cs.indiana.edu/sudoc/image_30000061709352/30000061709352/pdf/techdata.htm
Specific documents and manuals of the command module, of the lunar module and of the Saturn V launcher; preliminary and final reports and press kits for each mission.

Apollo TV
www.apollotv.net
Information on the television coverage of the Apollo missions.

Chariots for Apollo: A History of Manned Lunar Spacecraft
http://www.hq.nasa.gov/office/pao/History/SP-4205/contents.html
A meticulously detailed history of the Apollo spacecraft.

Clementine Color Images of the Moon/Clementine Lunar Map
ser.sese.asu.edu/MOON/clem_color.html
www.nrl.navy.mil/clm
Collections of the images acquired by the United States' Clementine lunar probe (1994).

Consolidated Lunar Atlas
www.lpi.usra.edu/resources/cla
Photographic atlas of the Moon.

Deepcold
www.deepcold.com
Military space projects of the United States and the Soviet Union.

Encyclopedia Astronautica
Astronautix.com
Vast collection of technical and historical information on Russian and American crewed spaceflights.

HORIZONS
ssd.jpl.nasa.gov/horizons.cgi
A NASA site that allows to calculate the apparent size, phase and position of any celestial body of our solar system as seen from any other body on any date (e.g., the appearance of the Earth as seen from the Moon).

Kaguya/Selene
wms.selene.jaxa.jp
www.jaxa.jp/projects/sat/selene/index_e.html
Technical data, photographs and videos from the Japanese Kaguya/Selene lunar probe (2007-2009).

Lunar Reconnaissance Orbiter
lunar.gsfc.nasa.gov
centauri.larc.nasa.gov/lro
Sites of the probe that obtained the first images of the Apollo spacecraft on the Moon in 2009.

Moonport
www.hq.nasa.gov/office/pao/History/SP-4204/cover.html
History of the lunar launch facilities of the United States.

NASA JSC Transcript Collection (Mercury to Apollo)
www.jsc.nasa.gov/history/mission_trans/mission_transcripts.htm
Collected transcripts of the radio communications of US crewed spaceflights.

NASA Office of Logic Design
klabs.org/history/history_docs/mit_docs/index.htm
Archive of documents related to the navigation and control computers of the Apollo spacecraft.

NASA Technical Reports Server
ntrs.nasa.gov
Huge collection of technical reports covering the entire US space program and the scientific knowledge gained from spaceflight.

PBS Race to the Moon
www.pbs.org/wgbh/amex/moon/index.html
Extensive site providing additional information in support of the PBS documentary *Race to the Moon*.

Radiation Effects and Analysis
radhome.gsfc.nasa.gov/top.htm
One of the main archives for documents regarding the effects of radiation in relation to spaceflight, managed by the Goddard Spaceflight Center.

Russian Space Web
www.russianspaceweb.com
News and history of the Russian space program.

The Apollo Program (1963-1972)
nssdc.gsfc.nasa.gov/planetary/lunar/apollo.html
Archive of the National Space Science Data Center, containing documents on all the Apollo missions, including the uncrewed test flights.

The Space Race
www.thespacerace.com
Site dedicated to the Mercury, Gemini and Apollo projects; not affiliated with NASA.

Unmanned Spaceflight
www.unmannedspaceflight.com
Site focusing on news regarding space missions by uncrewed vehicles.

We Choose the Moon
www.wechoosethemoon.org
Interactive site celebrating the fortieth anniversary of the first crewed Moon landing, with detailed animations, sounds and videos of all the key phases of the Apollo 11 mission.

Working on the Moon: Lessons from Apollo
workingonthemoon.com/index.html
Documents and experiences of the Apollo lunar excursions, reexamined for their usefulness for future crewed missions to the Moon.

15.3 Technical books and documents

35 Years Ago, "One Small Step...". Jack Yanosov. In *QST*, February 2005.

Adventures in Celestial Mechanics: A First Course in the Theory of Orbits. Victor G. Szebehely, University of Texas Press, Austin (1989).

ALSEP Data Handling Estimates. BellComm Memorandum for File B69 05062. R.J. Pauly (1969).

An Annotated Bibliography of the Apollo Program. Edited by Roger D. Launius and J.D. Hunley and published as *Monographs in Aerospace History,* no. 2 (1994).

An Introduction to Celestial Mechanics. Forest R. Moulton, Dover Publications, New York (1970).

An overview of medical-biological radiation hazards in earth orbits. M.C. Stauber, M. L. Rossi, E.G. Stassinopoulos, Goddard Space Flight Center (1984).

Apollo 7 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522645.

Apollo 8 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522661.

Apollo 9 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522513.

Apollo 10 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522688.

Apollo 10 Color Television, Westinghouse Defense and Space Center News Release (1969).

Apollo 10 Optical Tracking, in *Sky and Telescope*, July 1969, pages 62–63.

Apollo 11 – The NASA Mission Reports, Volume 1. Robert Godwin, Apogee Books; ISBN 189652253X.

Apollo 11 – The NASA Mission Reports, Volume 2. Robert Godwin, Apogee Books; ISBN 1896522491.

Apollo 11 – The NASA Mission Reports, Volume 3. Robert Godwin, Apogee Books; ISBN 1896522858.

Apollo 11 Photography, 70-mm, 16-mm and 35-mm Frame Index, National Space Science Data Center (1970).

Apollo 11 Technical Air-to-Ground Voice Transcription. Manned Spacecraft Center (1969).

Apollo 12 – The NASA Mission Reports, Volume 1. Robert Godwin, Apogee Books; ISBN 1896522548.

Apollo 12 – The NASA Mission Reports, Volume 2. Robert Godwin, Apogee Books; ISBN 1894959167.

Apollo 13 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522556.

Apollo 13 Television. Westinghouse press release, 1970.

Apollo 14 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522564.

Apollo 15 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522572.

Apollo 15 Final Lunar Surface Television Operations Plan. NASA Manned Spacecraft Center (1971).

Apollo 16 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522580.

Apollo 17 – The NASA Mission Reports. Robert Godwin, Apogee Books; ISBN 1896522599.

Apollo Black-and-White Television Scan Converter. M.V. Sullivan, *SMPTE Journal*, vol. 79, pages 621-625 (1970).

Apollo Color Television Camera. L.L. Niemyer, Jr., Westinghouse Defense and Space Center (1969).

Apollo Color Television Subsystem: Operation and Training Manual. Westinghouse (1971).

Apollo Experience Report – TV Systems. Paul P. Coan, Manned Spaceflight Center Television Subsystem Manager, *NASA Technical Note TN D-7476* (1973).

Apollo Lunar Landing Launch Window: the Controlling Factors and Constraints. Robin Wheeler, *Apollo Flight Journal*.

Apollo Lunar Television Camera: Operations Manual. Stan Lebar, Westinghouse Defense and Space Center (1968).

Apollo Unified S-Band System. K.E. Peltzer, Goddard Space Flight Center (1966).

Apollo: Race to the Moon. Charles Murray and Catherine Bly Cox. Touchstone Books (1990); ISBN 9780671706258.

Apollo: The Definitive Sourcebook. Richard W. Orloff, David M. Harland. Springer (2006); ISBN 0387300430.

Apollo - The Lost and Unflown Missions. David Shayler. Springer (2002); ISBN 9781852335755.

Communications on the Moon. In *Electronics World* (August 1969).

Comparison of Measured LM/EVA Link Transmission Losses on Apollo 15 with Predicted Values. BellComm Memorandum for File B71 12012. I.I. Rosenblum (1971).

EVA Communications from Surveyor III Site on Apollo 12. *BellComm Memorandum for File B69 10020*. I.I. Rosenblum (1969).

EVA VHF Communications with LM on Apollo 15 Traverses. BellComm Technical Memorandum TM-71-2034-2. I.I. Rosenblum (1971).

First Color TV from Space. Warren C. Wetmore, in *Aviation Week and Space Technology*, pages 18-20 (May 26, 1969).

Full Moon. Michael Light, Alfred A. Kropf (1999); ISBN 0375414940.

Fundamentals of Astrodynamics. Roger R. Bate, Donald D. Mueller, and Jerry E. White. Dover Publications, New York (1971).

Genesis: The Story of Apollo 8. Robert Zimmerman. Random House, New York (1998).

Ground Control Television Television Engineering Notebook. Richard Bohlmann et al., Manned Spacecraft Center (4/1971 - 4/1972).

Ground-Controlled Television Assembly: Final Report. RCA R-3901-F (1972).

Ground-Controlled Television Assembly: Interim Final Report. RCA R-3838F (1972).

Ground-Controlled Television Assembly: Operation and Checkout Manual. RCA (1971).

How Apollo Flew to the Moon. David Woods, Praxis Publishing (2008); ISBN 9780387716756.

Journey to the Moon: The History of the Apollo Guidance Computer. Eldon C. Hall. American Institute of Aeronautics and Astronautics, Reston, Va. (1996).

Liftoff: The Story of America's Adventure in Space. Michael Collins, Grove Press, New York (1988).

Live TV from the Moon. Dwight Steven-Boniecki (2010), Apogee Books; ISBN 9781926592169.

Lunar Module Reference. World Spaceflight News, Progressive Management (2000).

Lunar Television Camera: Pre-Installation Acceptance Test Plan. NASA/MSC-SESD-28-105 (1968).

Lunar TV Camera: Statement of Work (Final Draft). NASA/MSC (1966).

Mankind's Giant Leap. Robert Hotz, in *Aviation Week and Space Technology*, page 17 (July 28, 1969).

Manned Space Flight Network (MSFN) Postmission Report on the AS-506 (Apollo 11) Mission. Goddard Spaceflight Center (1970).

Mishin Monograph on Failure of Soviet Manned Lunar Program. In *JPRS Report*, 12 November 1991. Also available in French as *Pourquoi nous ne sommes pas allés sur la lune*. Vasily Mishin, Editions Cépaduès (1993).

Moon Boot - The Story of the Apollo Lunar Overshoe. David H. Mather, Moonandspace.com (2014). A digital edition is available at Issuu.com.

Moon Lander: How We Developed the Lunar Module. Thomas J. Kelly. Smithsonian History of Aviation and Spaceflight Series, Dominick Pisano et al., eds., Smithsonian Institution Press, Washington, D.C. (2001).

Moon Missions: Mankind's First Voyages to Another World. William F. Mellberg, Plymouth Press, Michigan (1997).

Moonfire: The Epic Journey of Apollo 11. Norman Mailer and Colum McCann, Taschen GmbH (2010); ISBN 978-38-3652-077-5.

Network Controller's Mission Report Apollo 11 (1969).

On the Radiation Hazards of Space Flight. James A. Van Allen, University of Iowa, in *Physics and Medicine of the Atmospheres and Space*, O. O. Benson Jr and Hubertus Strughold, John Wiley & Sons (1960).

Optical Observations of Apollo 12, in *Sky and Telescope*, February 1970, pages 127-130.

Optical Observations of Apollo 8. Harold B. Liemon, in *Sky and Telescope*, March 1969, pages 156-160.

Photography Equipment and Techniques - A Survey of NASA Developments. Albert J. Derr, Technology Utilization Office, NASA (1972).

Proceedings of the Apollo Unified S-Band Technical Conference, Goddard Space Flight Center, July 14-15, 1965. K.E. Peltzer, Goddard Spaceflight Center (1965).

Radiation Hazards to Crews of Interplanetary Missions: Biological Issues and Research Strategies. Task Group on the Biological Effects of Space Radiation, Space Studies Board, Commission on Physical Sciences, Mathematics, and Applications of the National Research Council. National Academy Press (1997).

Radiation Plan for the Apollo Lunar Mission (1969).

Red Star in Orbit. James E. Oberg, Random House (1981); ISBN 0394514297.

Remembering the Space Age. Steven J. Dick (ed.) (2008); ISBN 9780160817236.

Report of Apollo 204 Review Board (1967).

Review of Particle Properties. Particle Data Group, Lawrence Berkeley Laboratory (1999).

Shooting the Apollo Moonwalks. Sam Russell, in *Apollo Lunar Surface Journal*.

Star-Crossed Orbits. James E. Oberg (2002). McGraw Hill; ISBN 0071374256.

Summary of Medical Experience in the Apollo 7 Through 11 Manned Spaceflights. C.A. Berry, in *Aerospace Medicine* 41 (May 1970): 500-19.

The Apollo 13 Accident, in *Sky and Telescope*, July 1970, page 14.

The Apollo Guidance Computer - Architecture and Operation, Frank O'Brien (2010). Praxis Publishing Ltd; ISBN 9781441908766.

The Color War Goes to the Moon. Stan Lebar, in *Invention & Technology*, Summer 1997.

The Lunar Television Camera. E.L. Svensson, in *Westinghouse Engineer* no. 3, pages 46-51 (March 1968).

The Probability of an ALSEP Accepting an Erroneous Command – BellComm Memorandum for File B69 12007. J.E. Johnson (1969).

The Radiation Environment. J. Barth, Goddard Spaceflight Center.

Theory of Orbits. Victor G. Szebehely, Academic Press, New York (1967).

Tracking Apollo to the Moon. Lindsay Hamish, Springer-Verlag London (2001).

Trajectories in the Earth-Moon Space with Symmetrical Free Return Properties. Arthur J. Schwaninger, *NASA Technical Note D-1833* (1963).

TV Show of the Century: A Travelogue with No Atmosphere. Stanley Lebar and Charles P. Hoffman, in *Electronics* (1967).

Where No Flag Has Gone Before: Political and Technical Aspects of Placing a Flag on the Moon. Anne Platoff, *NASA Contractor Report 188251* (1993).

Where No Man Has Gone Before: A History of NASA's Apollo Lunar Expeditions. William David Compton. Dover Publications (2010); ISBN 9780486478883.

15.4 Biographies

A Man on the Moon: The Voyages of the Apollo Astronauts. Andrew Chaikin. Penguin Books, New York (1994). Republished by Penguin (2007); ISBN 014311235X.

All-American Boys: An Insider's Look at the U.S. Space Program. Walter Cunningham. First edition: MacMillan (1977); ISBN 0025292404. Reissue: Ipicturebooks (2010); ISBN 1876963247.

Apollo EECOM - Journey of a Lifetime. Sy Liebergot and David Harland. Apogee Books (2006); ISBN 9781894959889.

Carrying the Fire: An Astronaut's Journeys. Michael Collins. Farrar, Strauss, and Giroux (1974). Republished by Cooper Square Press (2001); ISBN 081541028X.

Countdown: An Autobiography. Frank Borman and Robert J. Serling. Silver Arrow Books (1988); ISBN 0688079296.

Failure Is Not an Option. Gene Kranz. Berkeley Publishing Group, New York (2000). Republished by Simon & Schuster (2009); ISBN 1439148813.

*Falling to Earth – An Apollo Astronaut's Journey to the Moo*n. Al Worden and Francis French. Smithsonian Books (2011); ISBN 9781588343093.

First Man: The Life of Neil A. Armstrong. James R. Hansen. Simon & Schuster (2006); ISBN 074325631-X.

Flight: My Life in Mission Control. Chris Kraft. Plume (2002); ISBN 0452283043.

From the Trench of Mission Control to the Craters of the Moon. Glynn Lunney, Jerry Bostick, David Reed, Charles Deiterich, Maurice Kennedy, William Boone, William Stoval. Blurb.com (2011).

Magnificent Desolation. Buzz Aldrin and Ken Abraham. Harmony Books (2009); ISBN 9780307463456.

Moon Shot: The Inside Story of America's Race to the Moon. Alan Shepard and Deke Slayton. Turner Publishing (1994); ISBN 1570361673.

Moondust: In Search of the Men Who Fell to Earth. Andrew Smith. Bloomsbury (2005); ISBN 0747563691.

Moonwalker. Charlie and Dotty Duke. Oliver-Nelson Books (1990); ISBN 0840791062.

The Last Man on the Moon. Eugene Cernan and Don Davis. St. Martin's Press, New York (1999); ISBN-10: 0312263511.

Two Sides of the Moon: Our Story of the Cold War Space Race. David Scott and Alexei Leonov. Pocket Books (2004); ISBN 0743450671.

15.5 Moon-related items, documents and memorabilia for purchase

Astronaut Store
www.astronautstore.org
Models, flight items and autographs. Site managed by the Mercury astronauts.

Collectionspace
www.collectionspace.it
Rare books, meteorite samples, autographs, flight items and models (in Italian).

Collectspace
www.collectspace.com
Autographs, items from space missions and models.

Footagevault
www.footagevault.com
High-definition digital transfers of spaceflight film and TV footage.

Kennedy Space Center
www.thespaceshop.com
Space-themed models, clothes, pins and other collectibles.

Moonpans
www.moonpans.com
Panoramic posters created by stitching together digitally the original photographs shot on the Moon.

Orbitec
www.orbitec.com
Regolith simulant (technical replica of moondust, used for testing lunar vehicles and instruments).

Spacecraft Films
www.spacecraftfilms.com
DVDs and Blu-rays containing the unabridged original footage of the flights; documentaries on the American space program.

Up-Ship
www.up-ship.com/drawndoc/drawndocspacesaturn.htm
Prints and technical blueprints of the Apollo spacecraft, of the Saturn rockets and of many other built or designed space vehicles.

15.6 Books by Moon hoax proponents

Dark Mission: The Secret History of NASA. Richard Hoagland and Mike Bara (2007). Feral House; ISBN 1-9325-9526-0.

Dark Moon: Apollo and the Whistle-Blowers. Mary Bennett and David S. Percy (2001). Adventures Unlimited Press; ISBN 0-9328-1390-9.

Der Mond ist ganz anders! Widersprüche und Falschaussagen. Gernot L. Geise (1985, 2003). EFODON e.V., Hohenpeißenberg; ISBN 3-9804300-6-5.

Die dunkle Seite von Apollo. Wer flog wirklich zum Mond? Gernot L. Geise (2002, 2006). Michaels-Verlag; ISBN 3-89539-607-9.

Die Schatten von Apollo. Hintergründe der gefälschten Mondflüge. Gernot L. Geise (2003). Michaels-Verlag, Edition EFODON; ISBN 3-89539-612-2.

Lumières sur la Lune – La NASA a t-elle menti!, Philippe Lheureux (2002). Editions Carnot; ISBN-10 2912362490. Published in English as *Moon Landings: Did NASA lie?* Philippe Lheureux (2003). Carnot USA Books; ISBN-10 1592090419.

NASA Mooned America! Ralph Rene, self-published (1994).

One Small Step? The Great Moon Hoax and the Race to Dominate Earth from Space. Gerhard Wisnewski (author) and Johanna Collis (translator) (2008). Clairview Books; ISBN 1905570120.

We Never Went to the Moon. Bill Kaysing, self-published (1974).

We Never Went to the Moon: America's Thirty Billion Dollar Swindle. Bill Kaysing and Randy Reid (1976). Health Research Books; ISBN 0-7873-0487-5.

15.7 Websites supporting Moon hoax theories

Atmosphärenfahrt-Index – die Beweise für die Mondlüge
www.geschichteinchronologie.ch/atmosphaerenfahrt-index.html (in German)

Aulis Online
www.aulis.com

Moonmovie
www.moonmovie.com

Wagging the Moondoggie
davesweb.cnchost.com

15.8 DVDs, videos and TV shows supporting hoax claims

A Funny Thing Happened on the Way to the Moon. Bart Sibrel (2001).

Apollo 11 Press Conference. Bart Sibrel (2004).

Apollo 11: Monkey Business. Bart Sibrel (2004).

Apollo One Accident Report. Bart Sibrel (2007).

Astronauts Gone Wild. Bart Sibrel (2004).

Conspiracy Theory: Did We Land on the Moon? Fox TV (2001).

Was it Only a Paper Moon? James M. Collier (1997).

What Happened on the Moon - An Investigation Into Apollo. David Groves and David Percy (2000).

15.9 Parodies that hoax proponents believe are true

Alternative 3 by Christopher Miles (Anglia Television, 1977).

Capricorn One by Peter Hyams (Associated General Films, 1978).

Dark Side of the Moon (Opération Lune) by William Karel (Arte France/Point du Jour, 2002).

Moontruth (The Viral Factory, 2002).

15.10 Books with rebuttals to Moon hoax claims

Bad Astronomy: Misconceptions and Misuses Revealed, from Astrology to the Moon Landing "Hoax". Phil Plait (2002). J. Wiley & Sons, ISBN 0471409766.

15.11 Neutral or debunking DVDs, videos and TV shows

Apollo 8: Leaving the Cradle (Spacecraft Films).

Apollo 11 (NEON/CNN, 2019).

Apollo 11: Men on the Moon (Spacecraft Films).

Apollo 11: A Night to Remember (BBC/Acorn Media, 2009).

Apollo 12: Ocean of Storms (Spacecraft Films).

Apollo 13: The Real Story (Spacecraft Films).

Apollo 14: To Fra Mauro (Spacecraft Films).

Apollo 15: Man Must Explore (Spacecraft Films).

Apollo 16: Journey to Descartes (Spacecraft Films).

Apollo 17: End of the Beginning (Spacecraft Films).

Apollo's Daring Mission (PBS, 2019).

Chasing the Moon (PBS, 2019).

First to the Moon: The Journey of Apollo 8 (Gravitas Ventures, 2019).

For All Mankind (Apollo Associates/FAM Productions, 1989).

In the Shadow of the Moon (Discovery Films/FilmFour, 2007).

Mission Control: The Unsung Heroes of Apollo (2017).

Moonscape (Paolo Attivissimo, 2014).

Moonwalk One (NASA/The Attic Room Ltd, 1970/2009).

Mythbusters – NASA Moon Landing (no. 104, August 27, 2008).

Penn & Teller: Bullshit! – Conspiracy Theories (no. 3-03, May 9, 2005).

The Last Man on the Moon (2014).

The Truth Behind the Moon Landings (Discovery Science, 2003).

When We Left Earth: The NASA Missions (Dangerous Films, 2008).

Live from the Moon (Spacecraft Films, 2010).

15.12 Moon hoax debunking sites

AboveTopSecret
www.abovetopsecret.com

ApolloHoax
www.apollohoax.net

Bad Astronomy
www.badastronomy.com/index.html

Clavius
www.clavius.org (also available in German at www.clavius.info)

Rocket and Space Technology
www.braeunig.us/space/

16 Apollo by the numbers

This chapter is a summary of the main technical, scientific and biographical information related to the flights and crews of the Apollo program and is intended as a concise quick reference for fact-checking, especially during any debates about Moon landing conspiracy theories.

16.1 Apollo landing sites



Figure 16.1-1. The Apollo landing sites. A11 - Mare Tranquillitatis (Sea of Tranquility), July 1969; A12 - Oceanus Procellarum (Ocean of Storms), November 1969; A14 - Fra Mauro, February 1971; A15 - Mare Imbrium (Sea of Rains), July 1971; A16 - Descartes Highlands, April 1972; A17 - Taurus-Littrow Valley, December 1972. Photo credit: PA.

16.2 The Apollo missions

Missions are listed chronologically. CM = Command Module; LM = Lunar Module; CDR = Commander; LMP = Lunar Module Pilot; CMP = Command Module Pilot.

16.2.1 AS-201

Crew: none.

Launcher: Saturn IB.

LM: none.

Lunar orbit: none.

CM and LM call signs: not assigned (CM was present; LM was not).

Launch and return dates: February 26, 1966.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned

Mission duration: 37 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: none. Automatic onboard movie cameras shot footage to acquire technical data.

Quantity of Moon rocks: none planned.

Rover: none.



Figure 16.2.1-1. Liftoff of Apollo-Saturn 201. Photo S66-22930 (NASA).

Notes: This was the first flight of a Saturn IB launcher, which consisted of an uprated version of the first stage of the Saturn I (launched successfully 10 times between October 1961 and July 1965) and a new second stage, the S-IVB, which would later become the third stage of the Saturn V. The flight was suborbital, reaching a maximum altitude of 488 kilometers (303 miles), and carried into space a Block I Apollo command and service module that had been modified specifically for this launch.

This mission tested the ignition and restarting of the service module engine and tested the structure and heat shield of the command module with a reentry that was slower (29,000 km/h, 18,000 mph) but steeper than those planned for crewed lunar missions.

16.2.2 AS-203

Crew: none.

Launch vehicle: Saturn IB.

LM: none.

Lunar orbit: none planned.

CM and LM call signs: none (no CM or LM present).

Launch and return dates: July 5, 1966.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 6 hours and 20 minutes

Time spent on the Moon: none planned.

Number of photographs taken: none. Automatic onboard TV and movie cameras recorded the behavior of the hydrogen in the fuel tanks.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: This flight was numerically out of sequence because it was scheduled initially as the third launch of the Saturn IB booster but was moved up due to delays in preparing the second scheduled flight.

AS-203 tested the behavior of the Instrument Unit and of the S-IVB stage, particularly of its fuel settling systems, in weightless conditions. It was also the first orbital flight of an S-IVB. The Apollo spacecraft was replaced with an aerodynamic fairing.

The system that provided continuous venting of the liquid hydrogen of the S-IVB was found to generate a modest but constant thrust that was sufficient, as expected, to settle the hydrogen in the tanks, preventing any weightless sloshing of the fuel, which would have prevented the stable supply of fuel to the engine. This was a key requirement in order to allow restarting of the J-2 engine of the S-IVB stage during a trip to the Moon.



Figure 16.2.2-1. Liftoff of Apollo-Saturn 203. Photo KSC-66PC-160.

16.2.3 AS-202

Crew: none.

Launch vehicle: Saturn IB.

LM: none.

Lunar orbit: none planned.

CM and LM call signs: not assigned (CM present, LM not present).

Launch and return dates: August 25, 1966.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 1 hour 33 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: none. Automatic onboard movie and TV cameras shot footage to acquire technical data.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: The main goals of this mission were testing the heat shield of the command module and performing structural qualification of the Saturn IB for carrying astronauts. Fuel cells were used for the first time as onboard power supply.



Figure 16.2.3-1. Liftoff of AS-202.

The command and service modules reached a maximum altitude of 1,144 kilometers (711 miles) along its suborbital path. The engine of the service module was started several times to demonstrate its restarting capability, which was essential for the maneuvers planned for flights to the Moon.

Reentry followed the intended trajectory, which made the Apollo command module "bounce" off the atmosphere, gaining altitude before final descent. This maneuver produced a double impact with the atmosphere and therefore generated a double peak in the heating of the heat shield which was very similar to the peak that would occur during crew return from the Moon. External temperature was estimated at 1,482 °C (2,700 °F); cabin temperature was 21 °C (70 °F).

16.2.4 Apollo 1 (AS-204)

Crew: Virgil Grissom (CDR), Edward White (Senior Pilot), Roger Chaffee (Pilot).

Launch vehicle: Saturn IB.

LM: none.

Lunar orbit: none planned.

CM and LM call signs: not assigned (CM present, LM not present).

Launch and return dates: January 27, 1967.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: not applicable.

Time spent on the Moon: none planned.

Number of photographs taken: none.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: The Apollo 1 flight, the first crewed mission of the Apollo program, was scheduled for liftoff on February 21, 1967, but the prime crew, consisting of Grissom, White and Chaffee, died in a fire inside the command module during a rehearsal of the countdown procedures on January 27, 1967.

The specific source of the fire was never pinpointed, but many materials used on board were flammable in the pure oxygen atmosphere at high pressure (1.13 atm, 16 psi) used for the test and combustion was initiated by an electrical short-circuit. Just seventeen seconds elapsed between the crew's first report of flames and the final radio transmission from the spacecraft. The internal overpressure made it impossible to open the hatch and attempt any rescue until



Figure 16.2.4-1. Left to right: Gus Grissom, Ed White and Roger Chaffee.

the pressure buildup ruptured the vehicle, far too late to save the crew.

This disaster delayed the crewed part of the Apollo project by 20 months. The Saturn IB launcher assigned to the Apollo 1 mission was later used for the first test flight of the lunar module (Apollo 5). The name *Apollo 1* was reserved by NASA and removed from the progressive numbering of the missions in honor of the three dead astronauts.

16.2.5 Apollo 4 (AS-501)

Crew: none.

Launch vehicle: Saturn V.

LM: present, but only as an engineering mockup.

Lunar orbit: none planned.

CM and LM call signs: not assigned (CM and LM both present).

Launch and return dates: November 9, 1967.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 8 hours 37 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: 715 (with 70 mm automatic still camera). Automatic onboard movie cameras shot footage to acquire technical data.



Figure 16.2.5-1. Liftoff of Apollo 4 (NASA).

Quantity of Moon rocks: none planned.

Rover: none.

Notes: This was the first flight of the Saturn V and qualified it for carrying astronauts. The noise generated at liftoff was so powerful that the launch tower was damaged severely and the buildings of the control center and the press room shook so much that ceiling panels fell around CBS reporter Walter Cronkite.

The Apollo capsule reached a maximum distance from Earth of 18,092 kilometers (11,240 miles) and was turned so as to expose one half to the Sun and keep the other half in shadow, creating the maximum temperature differential and assessing the ability of the spacecraft to withstand these extremes. Radiation shielding was also tested. The Service Module engine was restarted to accelerate the vehicle and create the worst possible reentry conditions that might occur during a return from the Moon. A Lunar Module engineering mockup was carried on board.

The spectacular movie footage of the separation of the interstage ring of this flight is often used in documentaries and movies but attributed to other missions.

16.2.6 Apollo 5 (AS-204R)

Crew: none.

Launch vehicle: Saturn IB.

LM: present, but legs were not installed.

Lunar orbit: none planned.

CM and LM call signs: not assigned (CM absent, LM present).

Launch and return dates: January 22-23, 1968.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.



Figure 16.2.6-1. Liftoff of Apollo 5. Photo S68-19456 (NASA/Archive.org).

Mission duration: 11 hours 10 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: none.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: The primary goal of this mission was to test in Earth orbit the Lunar Module and the Instrument Unit in the configuration that would be used for the Saturn V. The LM was legless because the legs weren't ready. The Saturn IB launcher from the Apollo 1 mission was reused.

This flight verified that the LM was able to adjust the thrust and orientation of the descent engine and to separate the descent stage from the ascent stage even in the extreme case of an abort during descent to the Moon.

The LM used for this flight suffered from many problems and delays. During a test on another LM being built, the windows had exploded due to the internal pressure, so this mission flew with aluminum panels to close the window openings.

The LM control software shut down the engine earlier than required and ground control had to intervene manually, but the flight was nonetheless considered a success.

16.2.7 Apollo 6 (AS-502)

Crew: none.

Launch vehicle: Saturn V.

LM: present, but only as an engineering mockup.

Lunar orbit: none planned.

CM and LM call signs: not assigned (CM and LM present).

Launch and return dates: April 4, 1968.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 9 hours 57 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: 370 (with 70 mm automatic still camera). Automatic onboard movie cameras shot footage to acquire technical data.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: This second test flight of the Saturn V aided in human-rating the giant launcher and testing the new Command Module hatch.

Violent longitudinal oscillations ("pogo"), intolerable for a crew, occurred during liftoff. One of the fairing panels of the Lunar Module suffered a structural failure and pieces of its covering came off. In the second stage, one engine shut down prematurely due to excessive vibrations and another one was shut down due to incorrect wiring; the onboard systems were forced to compensate for the error, leading to an orbit that was significantly different from the planned one.

These and other malfunctions and errors prevented completion of the original flight plan, which would have taken the spacecraft to a distance equal to the Moon's. The flight also used dedicated instruments to test radiation exposure inside the cabin. The often-used footage of the interstage ring separation is taken from this flight and from Apollo 4.



Figure 16.2.7-1. Liftoff of Apollo 6 (NASA).

16.2.8 Apollo 7 (AS-205)

Crew: Wally Schirra (CDR), Walter Cunningham (LMP), Donn Eisele (CMP).

Launch vehicle: Saturn IB.

LM: not present.

Lunar orbit: none planned.

CM and LM call signs: not assigned (CM present, LM absent).

Launch and return dates: October 11-22, 1968.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 10 days 20 hours 9 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: 532. Live TV broadcasts were also made.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: This was the first crewed flight of the Apollo spacecraft, 21 months after the Apollo 1 disaster, and tested all of its systems in Earth orbit. An orbital rendezvous was performed by using the S-IVB stage as a target, but no actual docking was carried out. The crew performed the United States' first live TV broadcast from space.

The astronauts came down with a head cold, which was particularly unpleasant in weightlessness, and this contributed to a sort of rebellion against the orders from Mission Control, especially on the matter of wearing helmets and gloves during reentry, as the crew was concerned that they would be unable to clear their noses and throats from the mucus accumulated in their heads, which would suddenly start flowing due to deceleration. Mission Control was instead concerned that any unexpected depressurization of the cabin would be lethal if the astronauts weren't wearing their full reentry gear. The astronauts made the final decision and went through reentry without helmets and gloves.



Figure 16.2.8-1. Left to right: Donn Eisele, Wally Schirra and Walt Cunningham, on the aircraft carrier USS Essex*, just after returning from their mission. Photo KSC-68PC-211, WallySchirra.com.*

Apollo 7 was the first US flight to use a mixed-gas atmosphere (65% oxygen, 35% nitrogen) instead of pure oxygen.

16.2.9 Apollo 8 (AS-503)

Crew: Frank Borman (CDR), William Anders (LMP), James Lovell (CMP).

Launch vehicle: Saturn V.

LM: present as a test article. Weight on Earth: 9,026 kg (19,900 lb).

Lunar orbit: yes (10 orbits).

CM and LM call signs: not assigned (CM and LM present).

Launch and return dates: December 21-27, 1968.

Lunar landing date and time: none.

Lunar landing site: none.



Figure 16.2.9-1. The Earth photographed from the Moon during Apollo 8. Photo AS8-14-2383.

Number of moonwalks: none planned.

Mission duration: 6 days 3 hours 0 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: 1,100. Live TV broadcasts were made and movie footage was shot.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: Apollo 8 was truly groundbreaking: the first crewed flight of a Saturn V, the first crewed mission to fly significantly far from the Earth and the first crewed flight around the Moon. The mission gave mankind the first photographs of the entire Earth taken by astronauts and the first live TV transmission of a crew from lunar orbit. Borman, Lovell and Anders were the first human beings to see the far side of the Moon with their own eyes.

This flight tested successfully the long-range communication and navigation equipment and methods needed for a mission to the Moon. The astronauts, however, were affected by headaches, vomiting and diarrhea in addition to sleeping problems, worsened by staggered sleep shifts and an excessive workload.

As the crew orbited the Moon, they read the first verses of the *Book of Genesis* live on TV, setting the record for the most watched broadcast in history (approximately 1 billion people in 64 countries).

16.2.10 Apollo 9 (AS-504)

Crew: James McDivitt (CDR), Russell Schweickart (LMP), David Scott (CMP).

Launch vehicle: Saturn V.

LM: present (LM-3). Weight on Earth: 14,530 kg (32,034 lb).

Lunar orbit: none (mission in Earth orbit).

CM and LM call signs: *Gumdrop*, *Spider*.

Launch and return dates: March 3-13, 1969.

Lunar landing date and time: none.



Figure 16.2.10-1. Dave Scott exits from the Command Module hatch, 6 March 1969. Photo AS09-20-3064.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 10 days 1 hour 0 minutes.

Time spent on the Moon: none planned.

Number of photographs taken: 1,373. TV broadcasts were made and movie footage was shot.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: This was the first flight of the complete Apollo spacecraft, including the Lunar Module, the first internal crew transfer between the two vehicles (from the Command Module to the Lunar Module and back), and the first docking, undocking and re-docking of the CM and LM. Schweickart performed the first spacewalk in a fully autonomous spacesuit (all previous spacewalks had used suits that depended on the spacecraft for cooling and oxygen).

McDivitt and Schweickart performed the first crewed flight of a spacecraft that was unable to reenter the atmosphere and used the LM's engines to fly up to 183 kilometers (114 miles) away from the CM and test the separation of the LM's ascent and descent stages.

The mission tested thoroughly and successfully the Apollo spacesuit and the Lunar Module, which were vital components for the Moon landings, as well as the communications, rendezvous, docking and crew transfer procedures. All these goals were achieved despite Schweickart's bouts of nausea and vomiting.

16.2.11 Apollo 10 (AS-505)

Crew: Tom Stafford (CDR), Gene Cernan (LMP), John Young (CMP).

Launch vehicle: Saturn V.

LM: present (LM-4). Weight on Earth: 13,941 kg (30,735 lb).

Lunar orbit: yes (31 orbits).

CM and LM call signs: *Charlie Brown*, *Snoopy*.

Launch and return dates: May 18-26, 1969.

Lunar landing date and time: none.

Lunar landing site: none.

Number of moonwalks: none planned.

Mission duration: 8 days 0 hours 3 minutes.

Time spent on the Moon: none planned.



Figure 16.2.11-1. The ascent stage of Apollo 10's Lunar Module climbs back from its lunar flight to dock with the Command Module. Detail of photo AS10-34-5108.

Number of photographs taken: 1,436. TV transmissions were broadcast and movie footage was shot.

Quantity of Moon rocks: none planned.

Rover: none.

Notes: This flight was a dress rehearsal of the actual Moon landing. It was the first lunar flight of the complete Apollo spacecraft and tested the LM, which undocked from the Command and Service Module for eight hours and descended to 14,450 meters (47,400 feet) from the surface of the Moon, with Stafford and Cernan on board, along a path that simulated the actual landing trajectory. The descent stage was then jettisoned and the astronauts used the ascent stage to climb back to the CM and dock, achieving the first rendezvous in lunar orbit. The first color TV transmissions from space were also broadcast.

Apollo 10 demonstrated Mission Control's ability to handle two spacecraft simultaneously at lunar distances, checked all the lunar descent procedures (except for the actual landing) and tested the LM's landing radar.

This flight holds the record for the highest speed ever attained by a crewed spacecraft: 39,937 km/h (24,815 mph), during the return from the Moon.

16.2.12 Apollo 11 (AS-506)

Crew: Neil Armstrong (CDR), Buzz Aldrin (LMP), Michael Collins (CMP).

Launch vehicle: Saturn V.

LM: present (LM-5). Weight on Earth: 15,095 kg (33,728 lb).

Lunar orbit: yes (30 orbits).

CM and LM call signs: *Columbia*, *Eagle*.

Launch and return dates: July 16-24, 1969.

Lunar landing date and time: July 20, 1969 20:17:39 GMT.

Lunar landing site: *Mare Tranquillitatis* (Sea of Tranquility).



Figure 16.2.12-1. Buzz Aldrin, photographed by Neil Armstrong, installing scientific instruments on the Moon. Photo AS11-40-5947.

Number of moonwalks: one (2 hours 31 minutes 40 seconds).

Mission duration: 8 days 3 hours 18 minutes.

Time spent on the Moon: 21 hours 36 minutes.

Number of photographs taken: 1,408, of which 339 on the Moon (121 of which were taken during the moonwalk). TV transmissions were broadcast and color movie footage was shot.

Quantity of Moon rocks: 21.55 kg (47.5 lb).

Rover: none.

Notes: This was mankind's first crewed landing on the Moon and the first return of samples and of very high resolution photographs from another celestial object, including panoramas, stereo images and extreme close-ups of the ground.

During landing, the onboard computer was overloaded with data and the automatic navigation system attempted to take the LM into an area strewn with boulders. Armstrong took control and steered the vehicle (with computer assistance) to a less dangerous area, but this deviation took so long that the LM landed with less than a minute of fuel left. The mission was a complete success and allowed the United States to keep President Kennedy's promise, made only eight years earlier, to land a man on the Moon and return him safely.

Armstrong and Aldrin's moonwalk began on July 21, 1969 at 2:56:15 GMT (22:56:15 EDT), 6 hours 39 minutes after landing. The maximum distance of the astronauts from the LM was approximately 60 meters (200 feet).

16.2.13 Apollo 12 (AS-507)

Crew: Pete Conrad (CDR), Alan Bean (LMP), Dick Gordon (CMP).

Launch vehicle: Saturn V.

LM: present (LM-6). Weight on Earth: 15,223 kg (33,652 lb).

Lunar orbit: yes (45 orbits).

CM and LM call signs: *Yankee Clipper*, *Intrepid*.

Launch and return dates: November 14-24, 1969.

Lunar landing date and time: November 19, 1969 6:54:35 UTC.

Lunar landing site: *Oceanus Procellarum* (Ocean of Storms).

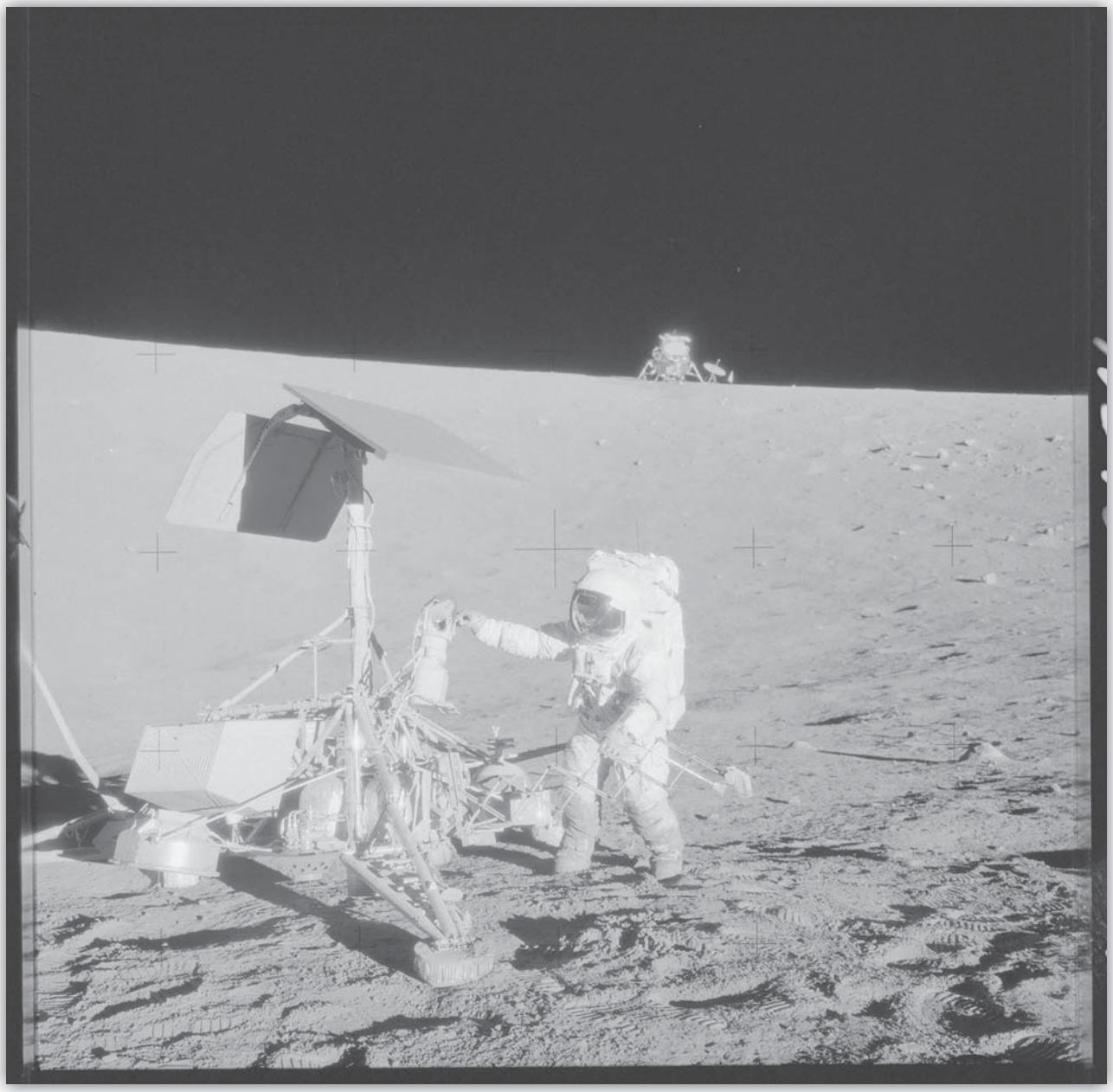


Figure 16.2.13-1. Pete Conrad inspects the Surveyor 3 probe on the Moon. Photo AS12-48-7134.

Number of moonwalks: 2 (3 hours 56 minutes; 3 hours 49 minutes).

Mission duration: 10 days 4 hours 36 minutes.

Time spent on the Moon: 1 day 7 hours 31 minutes.

Number of photographs taken: 2,119, of which 583 on the Moon. Color TV transmissions were broadcast and color movie footage was taken.

Quantity of Moon rocks: 34.3 kg (75.7 lb).

Rover: none.

Notes: The second crewed Moon landing demonstrated that pinpoint touchdown was possible: the LM landed just 185 meters (600 feet) from its target, the Surveyor 3 probe. This was the first (and so far the only) time that a crewed mission visited another space vehicle on another celestial body and returned some of its parts.

During liftoff, the Saturn V booster was struck twice by lightning, leading to multiple malfunctions. Only John Aaron's rapid reaction in Mission Control solved a situation that was leading to an extremely dangerous mission abort.

A color TV camera was used for the live broadcast of the moonwalk, but the camera failed because it was pointed briefly at the Sun, damaging its sensor.

This mission placed on the Moon instruments that were powered by a small nuclear generator, which kept them active for years, providing a constant stream of science data, which was later cross-referenced with the data from subsequent Apollo flights. Conrad and Bean walked up to 411 meters (1,350 feet) away from the LM.

16.2.14 Apollo 13 (AS-508)

Crew: James Lovell (CDR), Fred Haise (LMP), John Swigert (CMP).

Launch vehicle: Saturn V.

LM: present (LM-7). Weight on Earth: 15,192 kg (33,493 lb).

Lunar orbit: scheduled but replaced by a fly-around, setting the absolute crewed record for distance from Earth at 400,171 km (248,654 miles).

CM and LM call signs: *Odyssey*, *Aquarius*.

Launch and return dates: April 11-17, 1970.

Lunar landing date and time: scheduled but not performed.

Lunar landing site: Fra Mauro (not reached).

Number of moonwalks: None. EVAs were scheduled but not performed.

Mission duration: 5 days 22 hours 54 minutes.

Time spent on the Moon: None. Scheduled but not performed.

Number of photographs taken: 604 (none on the Moon). Color TV transmissions were broadcast and color movie footage was shot.

Quantity of Moon rocks: None. Collection was scheduled but not performed.

Rover: none.

Notes: A vital oxygen tank in the Service Module burst at 3:07:53 UTC on April 14, 1970, three days after liftoff from Earth on the way to the Moon, 322,000 kilometers (200,000 miles) from Earth. This depleted dramatically the oxygen reserves and the power available, since Apollo's fuel cells depended on the tank's oxygen to generate electricity. The historically famous phrase *"Houston, we have a problem"* was actually uttered by Swigert as *"OK, Houston, we've had a problem"*; Lovell then repeated *"Houston, we've had a problem"*. The plight of the Apollo 13 astronauts was followed live on TV all over the world.

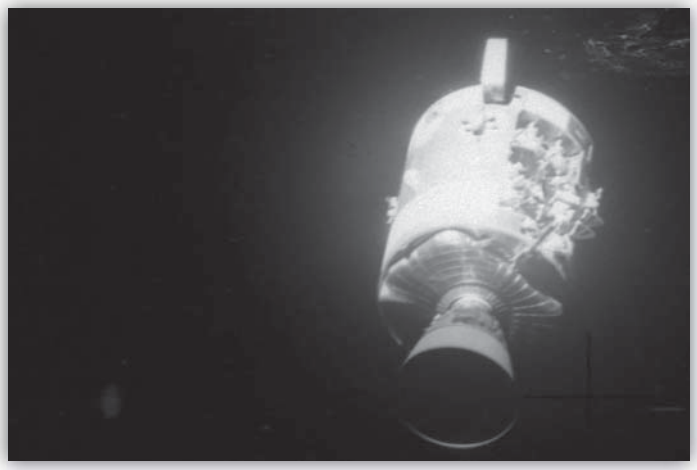


Figure 16.2.14-1. The Service Module of Apollo 13, ripped open by the explosion, is abandoned by the astronauts just before they reenter the Earth's atmosphere. Detail from photo AS13-59-8501. Whitish marks at top left are marker smudges on the film.

To save the astronauts, all the systems of the command module were shut down, producing an intense cold inside the spacecraft,

and the Lunar Module’s reserves and engine were used. The emergency trajectory forced Lovell, Haise and Swigert to fly all the way to the Moon, swing around it and then finally fly back to Earth, where they landed, in very poor physical shape but still standing, three days and 15 hours after the beginning of their ordeal.

16.2.15 Apollo 14 (AS-509)

Crew: Alan Shepard (CDR), Edgar Mitchell (LMP), Stuart Roosa (CMP).

Launch vehicle: Saturn V.

LM: present (LM-8). Weight on Earth: 15,279 kg (33,685 lb).

Lunar orbit: yes (34 orbits).

CM and LM call signs: *Kitty Hawk*, *Antares*.

Launch and return dates: January 31-February 9, 1971.

Lunar landing date and time: February 5, 1971 9:18:11 UTC.

Lunar landing site: Fra Mauro.



Figure 16.2.15-1. Alan Shepard holds the US flag on the Moon. Photo AS14-66-9232.

Number of moonwalks: 2 (4 hours 47 minutes; 4 hours 34 minutes).

Mission duration: 9 days 0 hours 1 minutes.

Time spent on the Moon: 1 day 9 hours 3 minutes.

Number of photographs taken: 1,338, of which 417 on the Moon. Color TV broadcasts were made and color movie footage was shot.

Quantity of Moon rocks: 42.3 kg (93.2 lb).

Rover: none. However, a manually propelled cart, termed *MET (Modular Equipment Transporter)*, was used.

Notes: During descent to the Moon, a false contact sent an incorrect signal to the LM's computer, bringing the spacecraft close to an automatic abort of the mission. Changes to the onboard software, performed on the fly to avoid this risk, caused a failure of the radar altimeter, which however recovered just in time to achieve landing.

At 47, Shepard set the record for the oldest moonwalker. In addition to their science tasks, Shepard hit some golf balls with a club he assembled by attaching a genuine #6 iron to the handle of the contingency sample tool and Mitchell threw the handle of a tool as if it were a javelin. Roosa carried on board the CM several hundred tree seeds, which were planted after the flight returned to Earth, giving rise to the so-called "Moon trees".

This was the first mission to use red stripes on the legs, arms and helmet to identify the commander (Apollo 13's suits already had this feature but were never used). Shepard and Mitchell set the walking distance record from the LM at 1.5 kilometers (about one mile) but were unable to climb to the destination of their second moonwalk, the 300-meter (1,000-ft) wide Cone Crater. Images of the landing site taken in 2009 revealed that after traveling approximately 400,000 kilometers (250,000 miles) the two astronauts missed Cone Crater by just 30 meters (about 90 feet).

16.2.16 Apollo 15 (AS-510)

Crew: David Scott (CDR), James Irwin (LMP), Alfred Worden (CMP).

Launch vehicle: Saturn V.

LM: present (LM-10). Weight on Earth: 16,437 kg (36,238 lb).

Lunar orbit: yes (74 orbits).

CM and LM call signs: *Endeavour*, *Falcon*.

Launch and return dates: July 26-August 7, 1971.

Lunar landing date and time: July 30, 1971 22:16:29 UTC.

Lunar landing site: near *Mare Imbrium* (Sea of Rains).

Number of moonwalks: 3 (6 h 32 m; 7 h 12 m; 4 h 49 m) plus a stand-up EVA: Scott, wearing his spacesuit, stood up through the LM's top docking hatch and scanned the surrounding area visually and photographically for 33 minutes.

Mission duration: 12 days 7 hours 11 minutes.

Time spent on the Moon: 2 days 18 hours 54 minutes.

Number of photographs taken: 2,640, of which 1,151 on the Moon. Color TV transmissions were made (including the liftoff of the LM from the Moon) and color movie footage was also shot.

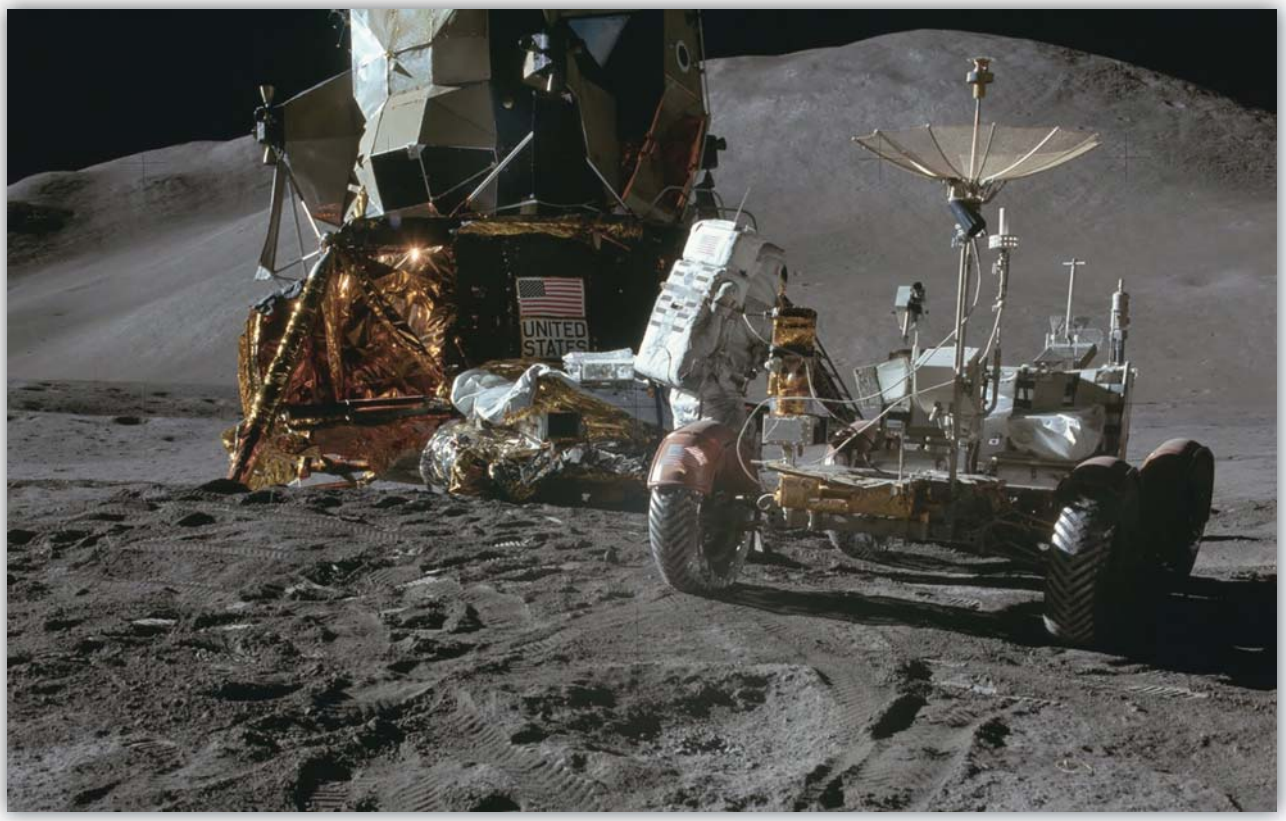


Figure 16.2.16-1. Jim Irwin next to the Lunar Rover. Detail of photo AS15-86-11598.

Quantity of Moon rocks: 77.3 kg (170.4 lb).

Rover: Yes, driven for a total of 27.9 km (17.3 miles).

Notes: This flight included the first use of the Rover lunar car, which allowed a far greater exploration range of up to 5 kilometers (3.1 miles) and made Scott the first car driver on another celestial object. Scott and Irwin were the first moonwalkers to perform three excursions and sleep on the Moon without wearing their spacesuits, which were improved and less rigid. They collected the *Genesis Rock*, one of the oldest Moon rocks returned to Earth, over 4 billion years old.

Worden launched a science subsatellite from the Service Module in lunar orbit. During the return trip, he performed the first deep-space spacewalk to recover the film canisters of the automatic mapping cameras.

During the third moonwalk, Scott dropped simultaneously a feather and a hammer to confirm Galileo’s theory that different bodies fell at the same rate in a vacuum. He also secretly placed on the Moon a small sculpture, the *Fallen Astronaut*, to honor the Russian and American space travelers whose deaths were publicly known at the time.

16.2.17 Apollo 16 (AS-511)

Crew: John Young (CDR), Charles Duke (LMP), Kenneth Mattingly (CMP).

Launch vehicle: Saturn V.

LM: present (LM-11). Weight on Earth: 16,437 kg (36,237 lb).

Lunar orbit: yes (64 orbits).

CM and LM call signs: *Casper*, *Orion*.

Launch and return dates: April 16-27, 1972.

Lunar landing date and time: April 21, 1972 2:23:35 UTC.

Lunar landing site: Descartes highlands.

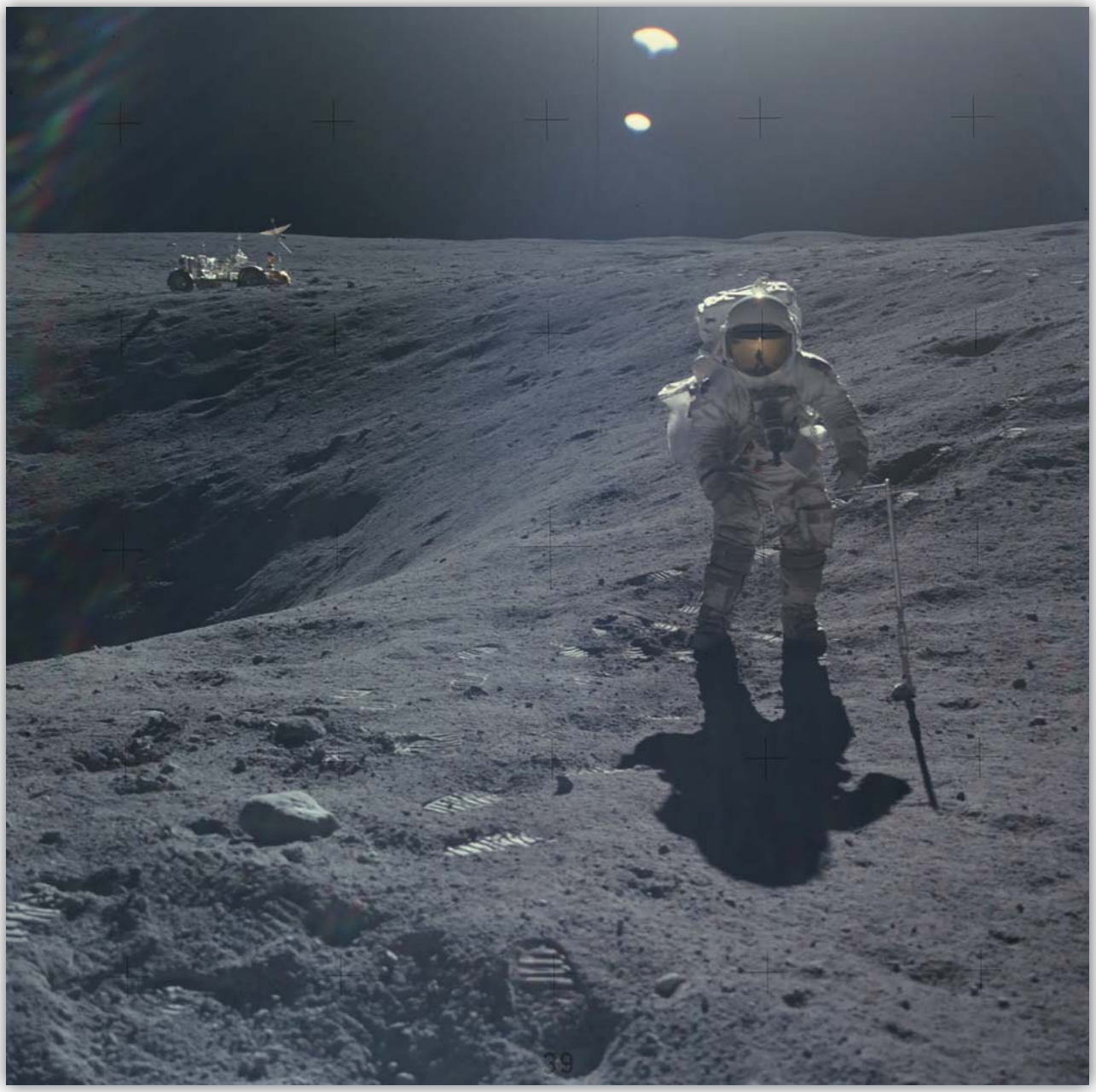


Figure 16.2.17-1. Charlie Duke on the Moon. Photo AS16-114-18423, processed to reduce internal reflections from the camera.

Number of moonwalks: 3 (7 h 11 m; 7 h 23 m; 5 h 40 m).

Mission duration: 11 days 1 hour 51 minutes.

Time spent on the Moon: 2 days 23 hours 2 minutes.

Number of photographs taken: 2,801, of which 1,787 on the Moon. Color TV transmissions were made (including the liftoff of the LM from the Moon) and color movie footage was also shot.

Quantity of Moon rocks: 95.7 kg (211 lb).

Rover: yes, for a total of 26.7 km (16.6 miles).

Notes: Young and Duke were the first astronauts to explore the highlands of the Moon. They spent a total of 20 hours on the Moon outside the LM and traveled for 26.7 km (16.6 miles) on the Rover, reaching a maximum distance of 4.6 km (2.8 miles) from their spacecraft. Young set the land speed record with the Rover, at 17.1 km/h (10.6 mph). Duke became the youngest moonwalker (he was 36). Apollo 16 had the highest elevation of the Sun above the horizon (48.7°).

During the first of their three moonwalks, the Apollo 16 astronauts collected the heaviest single sample, which weighed 11 kg (24 lb) and was named *Big Muley* in honor of Bill Muehlberger, director of geology operations for this mission. A photographic spectrograph/telescope, sensitive to far ultraviolet radiation, which on Earth is mostly blocked by the atmosphere, was used for the first time.

Mattingly, during the return trip, performed an hour-long spacewalk approximately 310,000 km (192,000 miles) from Earth while Duke leaned out of the Command Module hatch to help him. Mattingly's wedding ring, lost in the cabin a few day earlier, started to float out of the hatch, but Duke managed to catch it before it became lost in space.

16.2.18 Apollo 17 (AS-512)

Crew: Gene Cernan (CDR), Harrison Schmitt (LMP), Ron Evans (CMP).

Launch vehicle: Saturn V.

LM: present (LM-12). Weight on Earth: 16,448 kg (36,262 lb).

Lunar orbit: yes (75 orbits).

CM and LM call signs: *America*, *Challenger*.

Launch and return dates: December 7-19, 1972.

Lunar landing date and time: December 11, 1972 19:54:57 UTC.



Figure 16.2.18-1. Harrison Schmitt next to the Lunar Rover, photographed by Gene Cernan. Photo AS17-146-22386.

Lunar landing site: Taurus-Littrow Valley.

Number of moonwalks: 3 (7 h 11 m; 7 h 36 m; 7 h 15 m).

Mission duration: 12 days 13 hours 51 minutes.

Time spent on the Moon: 3 days 2 hours 59 minutes.

Number of photographs taken: 3,581, of which 2,237 on the Moon. Color TV transmissions were made (including the liftoff of the LM from the Moon) and color movie footage was also shot.

Quantity of Moon rocks: 110.5 kg (243.6 lb).

Rover: yes, for a total of 35.7 km (22.2 miles).

Notes: The last lunar mission of the Apollo project was the first night launch of a US crew, the longest stay on the Moon and in lunar orbit and as a whole the longest lunar mission. It used the heaviest Lunar Module (1,383 kg (3,050 lb) heavier than the one used for Apollo 11), returned the heaviest load of Moon rocks (five times more than Apollo 11), featured the first visit of a geologist (Schmitt) to another world, took the most photographs, covered the greatest distance in a single Rover excursion (20 kilometers (12.4 miles)), and ventured farthest from the LM (7.6 km (4.7 miles)).

Apollo 17 was also the only mission to investigate the nature of lunar soil by using gravimetric measurements and transmitting radio signals through the ground.

Gene Cernan was the last man to walk on the Moon: he left its surface to reenter the Lunar Module at 5:35 GMT on December 14, 1972. Since then, no one has visited the Moon.

This mission, like the previous one, also performed a 67-minute spacewalk during the return trip.

16.2.19 Skylab

In 1973 and 1974, three Apollo missions flew on Saturn IB launchers to Skylab, the United States' first space station in Earth orbit. Skylab was a converted S-IVB stage and was launched by a Saturn V on May 14, 1973. These flights provided invaluable science on Earth observations and on the effects of long-term weightlessness on human physiology, setting endurance records (28, 59 and 84 days) for their crews:

– Skylab 2 (May 25, 1973 - June 11, 1973): Pete Conrad, Paul Weitz, Joe Kerwin.

– Skylab 3 (July 28, 1973 - September 25, 1973): Alan Bean, Jack Lousma, Owen Garriott.

– Skylab 4 (November 16, 1973 - February 8, 1974): Gerald Carr, William Pogue, Ed Gibson.



Figure 16.2.19-1. Skylab as seen by the crew of Skylab 2 after the repairs they made (NASA).

16.2.20 Apollo-Soyuz

The *Apollo-Soyuz Test Project* was a joint flight (July 15-24, 1975) of an Apollo Command and Service Module, launched by a Saturn IB, and of a Soviet Soyuz spacecraft. The two vehicles performed a rendezvous and docking in Earth orbit, allowing their crews (astronauts Deke Slayton, Tom Stafford and Vance Brand; cosmonauts Alexei Leonov and Valeri Kubasov) to meet and demonstrate an unprecedented international collaboration in space.

This was the final flight of an Apollo spacecraft and the last spaceflight of an American astronaut for almost six years, until the first Space Shuttle mission, STS-1, lifted off 5 years and 264 days later, on April 12, 1981.



Figure 16.2.20-1. Alexei Leonov (left) and Deke Slayton (right) meet in space.

16.3 Apollo astronauts

This list provides the full name, year of birth and death, age at death, and mission(s) flown of every Apollo astronaut, sorted alphabetically by surname. The role and age during each Apollo mission is also given. Apollo 1 crew information is included as a tribute to their loss during preflight training. *"STS"* references a Space Shuttle flight.

This information is valid as of 1 July 2020.

Edwin Eugene "Buzz" Aldrin Jr (1930-) – Gemini 12, Apollo 11 (LMP, 39)

William Alison Anders (1933-) – Apollo 8 (LMP, 35)

Neil Alden Armstrong (1930-2012, 82) – Gemini 8, Apollo 11 (CDR, 38)

Alan LaVern Bean (1932-2018, 86) – Apollo 12 (LMP, 37), Skylab 3 (CDR, 41)

Frank Frederick Borman II (1928-) – Gemini 7, Apollo 8 (CDR, 40)

Vance DeVoe Brand (1931-) – Apollo-Soyuz (CMP, 44), STS-5, STS-41-B, STS-35

Gerald Paul Carr (1932-) – Skylab 4 (CDR, 41)

Eugene Andrew "Gene" Cernan (1934-2017, 82) – Gemini 9-A, Apollo 10 (LMP, 35), Apollo 17 (CDR, 38)

Roger Bruce Chaffee (1935-1967, 31) – Apollo 1 (Pilot, 31)

Michael Collins (1930-) – Gemini 10, Apollo 11 (CMP, 38)

Charles "Pete" Conrad Jr (1930-1999, 69) – Gemini 5, Gemini 11, Apollo 12 (CDR, 39), Skylab 2 (CDR, 43)

Ronnie Walter "Walt" Cunningham (1932-) – Apollo 7 (LMP, 36)

Charles Moss Duke Jr (1935-) – Apollo 16 (LMP, 36)

Donn Fulton Eisele (1930-1987, 57) – Apollo 7 (CMP, 38)

Ronald Ellwin Evans (1933-1990, 56) – Apollo 17 (CMP, 39)

Owen Kay Garriott (1930-2019, 89) – Skylab 3 (Science Pilot, 43), STS-9

Edward George Gibson (1936-) – Skylab 4 (Science Pilot, 38)

Richard Francis "Dick" Gordon Jr (1929-2017, 88) – Gemini 11, Apollo 12 (CMP, 40)

Virgil Ivan "Gus" Grissom (1926-1967, 40) – Mercury 4, Gemini 3, Apollo 1 (CDR, 40)

Fred Wallace Haise Jr (1933-) – Apollo 13 (LMP, 36)

James Benson Irwin (1930-1991, 61) – Apollo 15 (LMP, 41)

Joseph Peter Kerwin (1932-) – Skylab 2 (Science Pilot, 41)

James Arthur Lovell Jr (1928-) – Gemini 7, Gemini 12, Apollo 8 (CMP, 40), Apollo 13 (CDR, 42)

Jack Robert Lousma (1936-) – Skylab 3 (Pilot, 37), STS-3

Thomas Kenneth "Ken" Mattingly II (1936-) – Apollo 16 (CMP, 36), STS-4, STS-51-C

James Alton McDivitt (1929-) – Gemini 4, Apollo 9 (CDR, 39)

Edgar Dean Mitchell (1930-2016, 85) – Apollo 14 (LMP, 40)

William Reid Pogue (1930-2014, 84) – Skylab 4 (Pilot, 43)

Stuart Allen Roosa (1933-1994, 61) – Apollo 14 (CMP, 37)

Walter Marty "Wally" Schirra (1923-2007, 84) – Mercury 8, Gemini 6A, Apollo 7 (CDR, 45)

Harrison Hagan Schmitt (1935-) – Apollo 17 (LMP, 37)

Russell Louis "Rusty" Schweickart (1935-) – Apollo 9 (LMP, 33)

David Randolph Scott (1932-) – Gemini 8, Apollo 9 (CMP, 36), Apollo 15 (CDR, 39)

Alan Bartlett Shepard Jr (1923-1998, 74) – Mercury 3, Apollo 14 (CDR, 47)

Donald Kent "Deke" Slayton (1924-1993, 69) – Apollo-Soyuz (Docking Module Pilot, 51)

Thomas Patten Stafford (1930-) – Gemini 6-A, Gemini 9-A, Apollo 10 (CDR, 39), Apollo-Soyuz (CDR, 45)

John Leonard "Jack" Swigert Jr (1931-1982, 51) – Apollo 13 (CMP, 38)

Paul Joseph Weitz (1932-2017, 85) – Skylab 2 (Pilot, 41), STS-6

Edward Higgins White II (1930-1967, 36) – Gemini 4, Apollo 1 (Senior Pilot, 36)

Alfred Merrill Worden (1932-2020) – Apollo 15 (CMP, 39)

John Watts Young (1930-2018, 88) – Gemini 3, Gemini 10, Apollo 10 (38), Apollo 16 (CDR, 41), STS-1, STS-9

Astronauts who flew around the Moon. Only 24 people, all American white males, have ever left low Earth orbit and flown to the Moon at least once, on Apollo 8, 10 and 13 (circumlunar flights) and Apollo 11, 12, 14, 15, 16 and 17 (lunar landing flights). Eleven of them are still alive: Buzz Aldrin, William Anders, Frank Borman, Michael Collins, Charles Duke, Fred Haise, James Lovell, Ken Mattingly, Harrison Schmitt, David Scott, and Thomas Stafford. Thirteen have died: Neil Armstrong, Alan Bean, Eugene Cernan, Charles Conrad, Ron Evans, Richard Gordon, James Irwin, Edgar Mitchell, Stuart Roosa, Alan Shepard, John Swigert, Alfred Worden, and John Young.

Moonwalkers. Only 12 of the 24 circumlunar astronauts walked on the Moon. Four are still alive: Buzz Aldrin (Apollo 11), David Scott (Apollo 15), Charles Duke (Apollo 16), and Harrison Schmitt (Apollo 17). Eight are no longer with us: Neil Armstrong (Apollo 11), Alan Bean (Apollo 12), Charles Conrad (Apollo 12), Edgar Mitchell (Apollo 14), Alan Shepard (Apollo 14), James Irwin (Apollo 15), John Young (Apollo 16), and Gene Cernan (Apollo 17).

Multiple trips to the Moon. Three astronauts flew to the Moon twice: James Lovell (Apollo 8 and 13), John Young (Apollo 10 and 16) and Eugene Cernan (Apollo 10 and 17). Lovell was the only astronaut to fly twice to the Moon without ever setting foot on it: Young and Cernan landed on the Moon during their second trips.

16.4 The Saturn V/Apollo spacecraft

Overall dimensions and weight. Height: 111 m (363 ft). Diameter (at the base, not including the fins): 10 m (33 ft). Weight: 2,822 t (6.2 million lb, Apollo 8) to 2,965 t (6.5 million lb, Apollo 16).

First stage (S-IC)

Dimensions and weights. Height: 42 m (138 ft). Diameter: 10 m (33 ft). Weight without fuel: 129,822 kg (286,208 lb, Apollo 15) to 138,451 kg (305,232 lb, Apollo 8). Fully fueled weight: 2,175,939 kg (4,797,126 lb, Apollo 8) to 2,288,088 kg (5,044,371 lb, Apollo 16).

Fuel load. RP-1 kerosene and liquid oxygen, 2,034,664 kg (4,485,668 lb, Apollo 8) to 2,155,071 kg (4,751,120 lb, Apollo 16). Burn rate: 12,437 kg/s (27,420 lb/s, Apollo 13) to 12,741 kg/s (28,089 lb/s, Apollo 15).

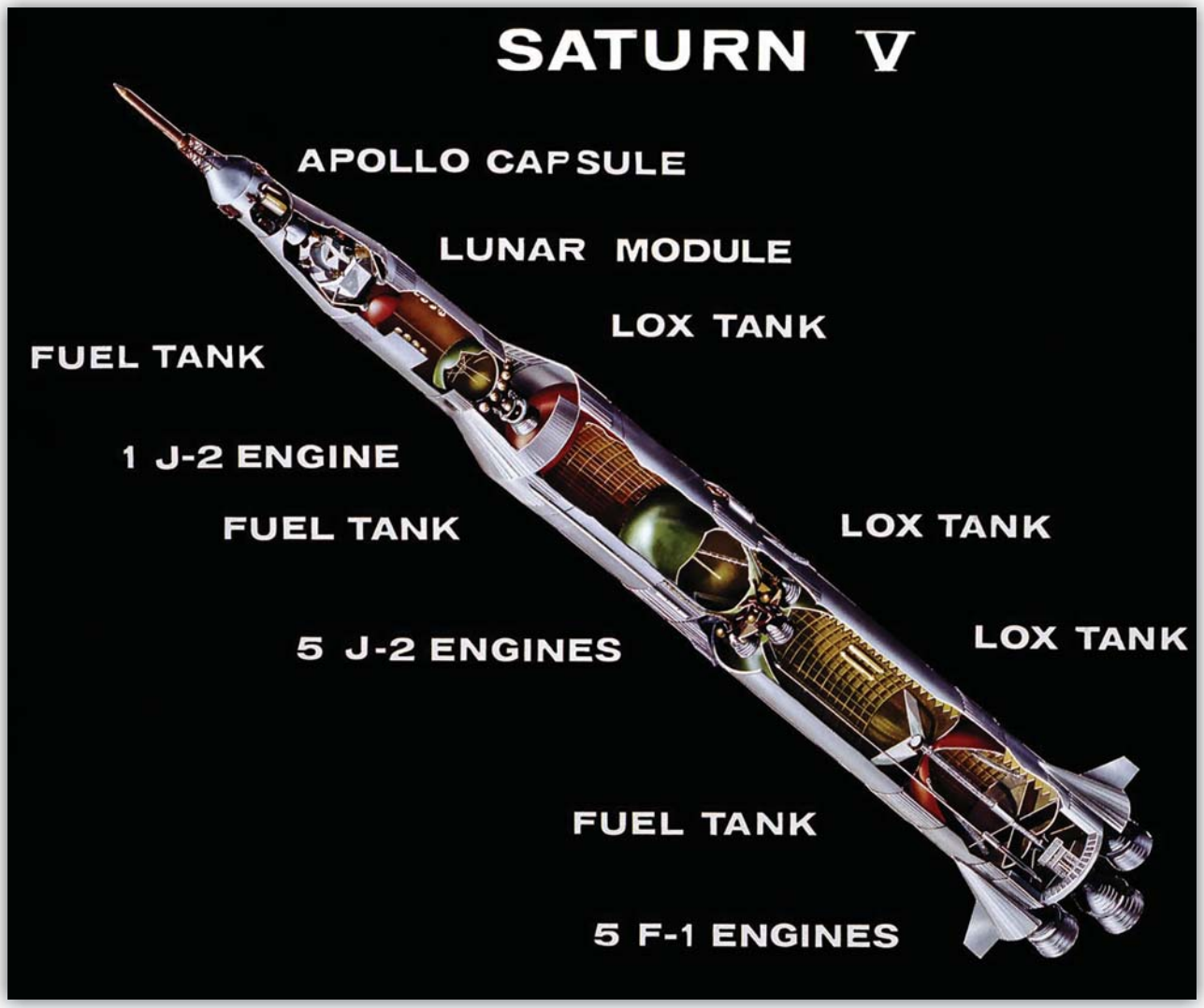


Figure 16.4-1. Cutout illustration of the Saturn V/Apollo vehicle (1967). Credit: Dan Beaumont.

Propulsion. 5 F-1 engines (4 gimbaling, 1 fixed). Total rated thrust: 3,401,940 kg (7.5 million lb, Apollo 8) to 3,451,840 kg (7.61 million lb, all other flights).

Second stage (S-II)

Dimensions and weights. Height: 25 m (138 ft). Diameter: 10 m (33 ft). Weight without fuel: 35,356 kg (77,947 lb, Apollo 13) to 40,142 kg (88,500 lb, Apollo 8). Fully fueled weight: 471,114 kg (1,038,628 lb, Apollo 8) to 493,536 kg (1,088,061 lb, Apollo 16).

Fuel load. Liquid hydrogen and liquid oxygen, 430,324 kg (948,702 lb, Apollo 8) to 456,635 kg (1,006,708 lb, Apollo 16).

Propulsion. 5 J-2 engines (4 gimbaling, 1 fixed). Total rated thrust: 510,291 kg (1.12 million lb, Apollo 8) to 521,631 kg (1.15 million lb, all other flights).

Third stage (S-IVB)

Dimensions and weights. Height: 17.8 m (58.5 ft). Diameter: 6.6 m (21.7 ft). Weight without fuel: 9,912 kg (21,852 lb, Apollo 7) to 11,760 kg (25,926 lb, Apollo 8). Fully fueled weight: 116,357 kg (256,523 lb, Apollo 7) to 120,798 kg (266,315 lb, Apollo 15).

Fuel load. Liquid hydrogen and liquid oxygen, 105,866 kg (233,395 lb, Apollo 9) to 108,618 kg (239,462 lb, Apollo 15).

Propulsion. One J-2 restartable engine. Rated thrust: 104,326 kg (230,000 lb).

Command and service module (CSM)

Dimensions and weights. CM height: 3.47 m (11.4 ft). SM height (including engine bell): 7.5 m (24.6 ft). CM diameter: 3.91 m (128.ft). SM diameter: 3.91 m (12.8 ft). Crew volume in CM: 6 m^3 (210 cu ft). CM fueled weight: 5,557 kg (12,250 lb, Apollo 11) to 5,840 kg (12,874 lb, Apollo 17). SM fueled weight: 18,413 kg (40,593 lb).

Fuel load. Aerozine 50 (50% hydrazine, 50% unsymmetric dimethyl hydrazine) and dinitrogen tetroxide, hypergolic.

Propulsion. CM: only maneuvering thrusters. SM: one main engine and 16 maneuvering thrusters. SM main engine thrust: 9,298 kg (20,500 lb).

Launch Escape System (LES)

Dimensions and weight. Height: 10 m (33 ft). Diameter: 0.66 m (26 in). Fully fueled weight: 4,042 kg (8,910 lb).

Fuel. Solid compound based on polysulfides.

Propulsion. One main motor, one maneuvering motor and one jettison motor, all solid-fueled. Main engine thrust: 66,678 kg (147,000 lb).

Spacecraft/Lunar Module Adapter (SLA)

Dimensions and weight. Height: 8.53 m (28 ft). Diameter: 6.60 m (260 in) at the base, 3.91 m (154 in) at the top. Weight: 1,814 kg (4,000 lb).

Fuel and propulsion. None.

Lunar Module (LM)

Dimensions and weights. Height: 7.29 m (23 ft). Distance between outer ends of legs (deployed): 9.4 m (31 ft). Length of three probes under footpads: 173 cm (68 inches). Diameter of the four footpads: 81 cm (32 in). Total surface of four footpads: 20,750 cm^2 (3,216 sq in). Cabin volume: 6.7 m^3 (235 cu ft), of which 4.5 m^3 (160 cu ft) habitable. Weight: 13,941 kg (30,735 lb, Apollo 10) to 16,448 kg (36,262 lb, Apollo 17).

Fuel load. Aerozine 50 (50% hydrazine, 50% unsymmetric dimethyl hydrazine) and dinitrogen tetroxide, hypergolic; 2,365 kg (5,214 lb) in the ascent stage, 8,100 kg (18,100 lb) in the descent stage.

Engines. Descent stage: one, with throttleable thrust (476-4,380 kg; 1,050-9,870 lb) and gimbaling nozzle. Ascent stage: one primary engine, with fixed thrust (1,589 kg; 3,500 lb) and fixed nozzle, and 16 attitude control thrusters.

Saturn V onboard computer (*Instrument Unit*)

Dimensions and weight. Height: 0.91 m (3 ft). Diameter: 6.6 m (21 ft 8 in). Weight: 1,953 kg (4,306 lb).

Lunar Rover

Dimensions and weights. Length: 2.96 m (116.5 in). Width: 2.06 m (81 in). Height: 1.14 m (44.8 in). Wheelbase: 2.28 m (90 in). Weight: 209.6 kg (462 lb) on Earth, 34.8 kg (77 lb) on the Moon.

Top speed. 13 km/h (8 mph).

Propulsion. 4 electric driving motors; 2 electric motors for the steering system of the 4 steerable wheels.

Cost. 38 million dollars for 5 complete vehicles plus three test vehicles and associated training.

Space suits

Weights. Including the PLSS, approximately 81 kg (180 lb) on Earth or 13.5 kg (30 lb) on the Moon. The PLSS alone weighed approximately 27 kg (60 lb) on Earth or 4.5 kg (10 lb) on the Moon.

Apollo onboard computer (CM/LM)

RAM. 4,096 words of 16 bits = 64,000 bit = approximately 8 kbytes.

Clock. 2.048 MHz.

1202 error. Solved by Steven Bales and Jack Garman.

16.5 Moon rocks

Total collected Moon rocks. Approximately 382 kg (842 lb). The heaviest single rock (*"Big Muley"*, Apollo 16) weighs 11.7 kg (25.9 lb).



Figure 16.5-1. Apollo lunar rock sample 15498 at the Lunar Sample Vault in Houston. Credit: OptoMechEngineer/Wikimedia.

16.6 Photographs

SO-368 film. Kodak Ektachrome MS color reversal film, ASA 64, 70 mm, double perforation, Estar polyester backing. Used for color photographs outside the LM on Apollo 11.

SO-168 film. Kodak Ektachrome EF color reversal film, ASA 160 (pushed to 1000 ASA for onboard photographs), 70 mm. Used for the ALSCC (stereoscopic lunar surface close-up camera) and for color photographs on all flights except Apollo 11, which used it only for onboard photos.



Figure 16.6-1. First-generation duplicate of a film used during the Apollo 11 mission and previously owned by Buzz Aldrin. Credit: Heritage Auctions.

Type 3400 (HBW) film. Kodak Panatomic-X black and white 70 mm film, ASA 80. Used for the Apollo 11 black and white photographs.

SO-267 (HBW) film. Plus-XX black and white film, ASA 278. Used for photographs outside the LM during Apollo 12 and 14.

Type 3401 (HBW). Plus-XX black and white film, ASA 80-125. Used for photographs outside the LM on Apollo 15, 16 and 17.

Magazine. 160 color photographs, 200 black-and-white.



Figure 16.6-2. An Apollo Hasselblad camera magazine with settings for the various lighting conditions on the Moon.

Total of photographs taken on the surface of the Moon. Over 17,000.

Exposure settings. Aperture: f/5.6, f/8 or f/11. Shutter speed: 1/250, except for some photographs with polarization, taken at 1/125.



16.7 The Moon and the Earth

Earth-Moon distance (center to center). Average: 384,403 km (238,857 miles), equal to about 30 Earth diameters. Minimum: 363,104 km (225,622 miles). Maximum distance: 405,696 km (252,088 miles).

Diameter of the Moon. 3,474 km (2,158 miles), 1/4 of the Earth's diameter.

Diameter of the Earth. 12,740 km (7,916 miles).

Orbit around the Earth. Every 27.3 Earth days.

Lunar escape velocity. 2.38 km/s (5,323 mph).

Albedo of the Moon. 0.12. The light reflected by the Moon at first quarter or last quarter, i.e., when half of a sunlit hemisphere is visible from Earth, is only 8% of the light reflected by a full Moon.

Temperature at the surface. Average 107°C (224.7°F), maximum 123°C (253.4°F), minimum -153°C (243.4°F). Minimum temperature can drop to -233°C (-387.4°F) in polar regions that are permanently in shadow. At a depth of 1 m (40 in), the temperature is almost constant at -35°C (-31°F).

Distance of the horizon. 2.4 km (1.5 miles) on the Moon; 4.7 km (3 miles) on Earth.

Duration of lunar day and night. 340 hours each.

Size of the Earth in the lunar sky. About 3.6 times the diameter of the Moon in the Earth's sky.

Brightness of the Earth in the lunar sky. 40 times that of a full Moon.

Figure 16.7-1. The Earth-Moon system to scale. Credit: Wikimedia.

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