*ad*Astra

APOLLO 11
50TH ANNIVERSARY
SPECIAL EDITION

THE REAL BUZZ
AN EXCLUSIVE INTERVIEW WITH BUZZ ALDRIN

EYEWITNESS TO HISTORY
NEW IMAGES FROM APOLLO 11

APOLLO IN 3D
AUGMENTED REALITY FEATURE

FIRST ON THE MOON
APOLLO 11'S DANGEROUS MISSION

INSIDE NEIL ARMSTRONG
AN EXCLUSIVE Q&A WITH JAMES HANSEN, AUTHOR OF "FIRST MAN"

the magazine of the
National Space Society
DEDICATED TO THE CREATION OF A SPACEFARING CIVILIZATION

2019-2 || space.nss.org

NSS
National Space Society

EXCLUSIVE OFFER FOR NSS MEMBERS

*APR = Annual Percentage Rate. 9.9% APR is only available to qualified members on balance transfers made within 90-days after account opening. Balance transfers made after that time would be made at the standard Balance Transfer APR (12.15%-17.99%). Minimum transfer amount is $500. Balance transfers must be from another financial institution and cannot be from any NASA Federal credit card. The total transferred may not exceed your available credit card limit. There are no balance transfer fees. Purchase APR (12.15%-17.99%).

Cash Advance APR (14.15%-18%). All APRs are based on creditworthiness and will vary with the market based on the Prime Rate. The penalty APR of 18% may be applied if you make a late payment. Cash advance fee: 3% of the advance ($5 minimum). Rates as of April 1, 2019 and are subject to change. Eligibility and Membership in NASA FCU required. All offers subject to credit approval.

[1] See terms and conditions for more details nasafcu.com/platinum-advantage-rewards-credit-card-terms. Federally insured by NCUA.

COVER ILLUSTRATION: "First Man"

CREDIT: James Vaughan

Contributors + Columnists

Spring 2019
Volume 31 • Issue 2

Al Anzaldua
Emily Carney
Jack Hagerty
John F. Kross
Martin Lollar
Claire Stephens McMurray
Clifford R. McMurray
Geoffrey Notkin
Anthony Paustian
Rod Pyle
Dale Skran

EDITORS NOTE: The cover of the Winter 2019 edition of Ad Astra was based on an ice mining concept developed by the Colorado School of Mines and conceptual artwork produced by United Launch Alliance. We apologize for omitting this attribution.

adAstra the magazine of the **National Space Society**

PUBLISHER
National Space Society

EDITOR-IN-CHIEF
Rod Pyle

MANAGING EDITOR
Aggie Kobrin

COPY EDITOR
Shaun Kobrin

ART DIRECTION + GRAPHIC DESIGN
Michele Rodriguez

DIRECTOR OF ACCOUNTING
Andrew Jens

MEMBERSHIP + CHAPTER SERVICES
Jill Jackson

PRINTING + MAILING
Publication Printers
Denver, CO

ADVERTISING CONTACT
Aggie Kobrin
949.836.8464
aggie.kobrin@nss.org

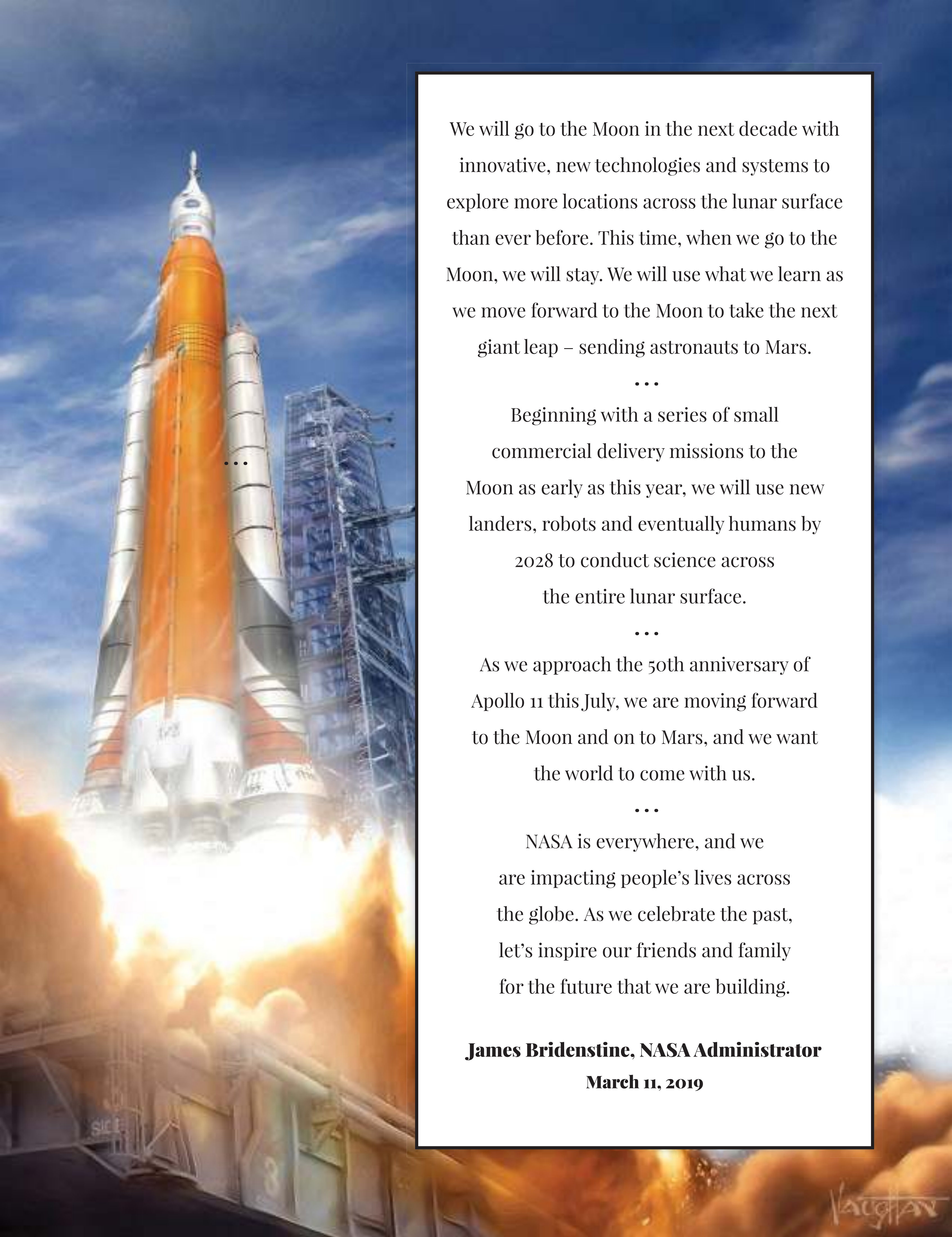
Joseph M. Rauscher
j-rauscher@colab.nss.org

"Ad Astra" is published quarterly by the National Space Society at 11130 Sunrise Valley Dr., Suite 350, Reston, VA 20191.

For questions about membership, please contact Jill Jackson at 202.424.2899.

Periodicals postage paid at Washington, D.C., and additional mailing offices.

POSTMASTER: Send address changes to the National Space Society 11130 Sunrise Valley Dr., Suite 350, Reston, VA 20191



We will go to the Moon in the next decade with innovative, new technologies and systems to explore more locations across the lunar surface than ever before. This time, when we go to the Moon, we will stay. We will use what we learn as we move forward to the Moon to take the next giant leap – sending astronauts to Mars.

. . .

Beginning with a series of small commercial delivery missions to the Moon as early as this year, we will use new landers, robots and eventually humans by 2028 to conduct science across the entire lunar surface.

. . .

As we approach the 50th anniversary of Apollo 11 this July, we are moving forward to the Moon and on to Mars, and we want the world to come with us.

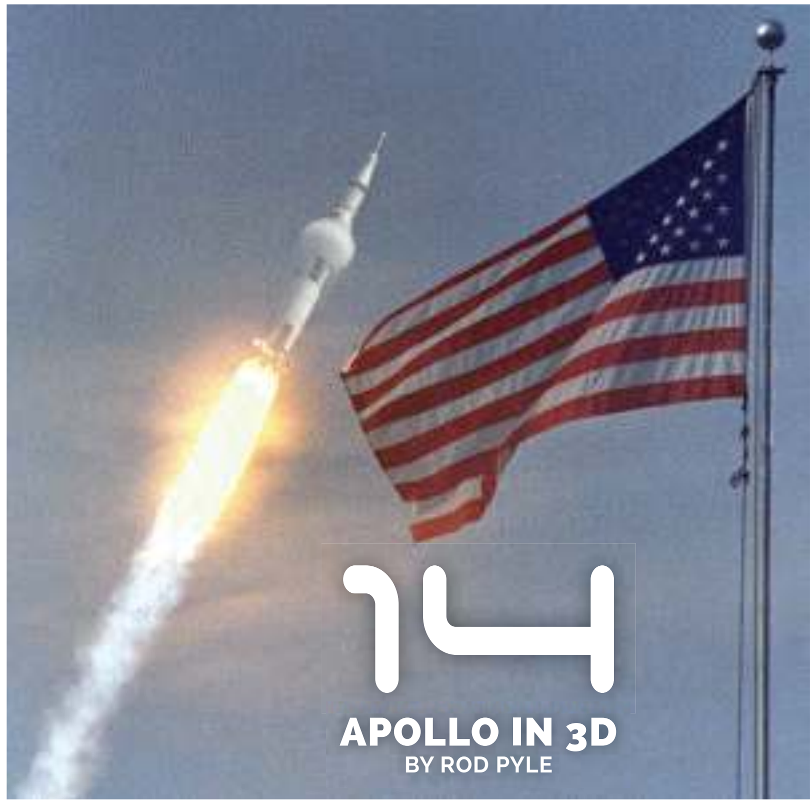
. . .

NASA is everywhere, and we are impacting people's lives across the globe. As we celebrate the past, let's inspire our friends and family for the future that we are building.

James Bridenstine, NASA Administrator
March 11, 2019

Contents

FEATURES



Contents

DEPARTMENTS

COMMS

SETTING THE STAGE

APOLLO'S LEGACY

A MISSION TO THE MOON

NSS, ON A MISSION TO THE STARS

AVAILABLE WHERE BOOKS ARE SOLD

SPACE 2.0

FOREWORD BY BUZZ ALDRIN

"…an engaging and expertly-informed explanation of how we got this far, along with a factual yet inspiring intro to our around-the-corner new adventures in space. Strap yourself in tight. It's a fascinating ride! Have spacesuit, will travel."

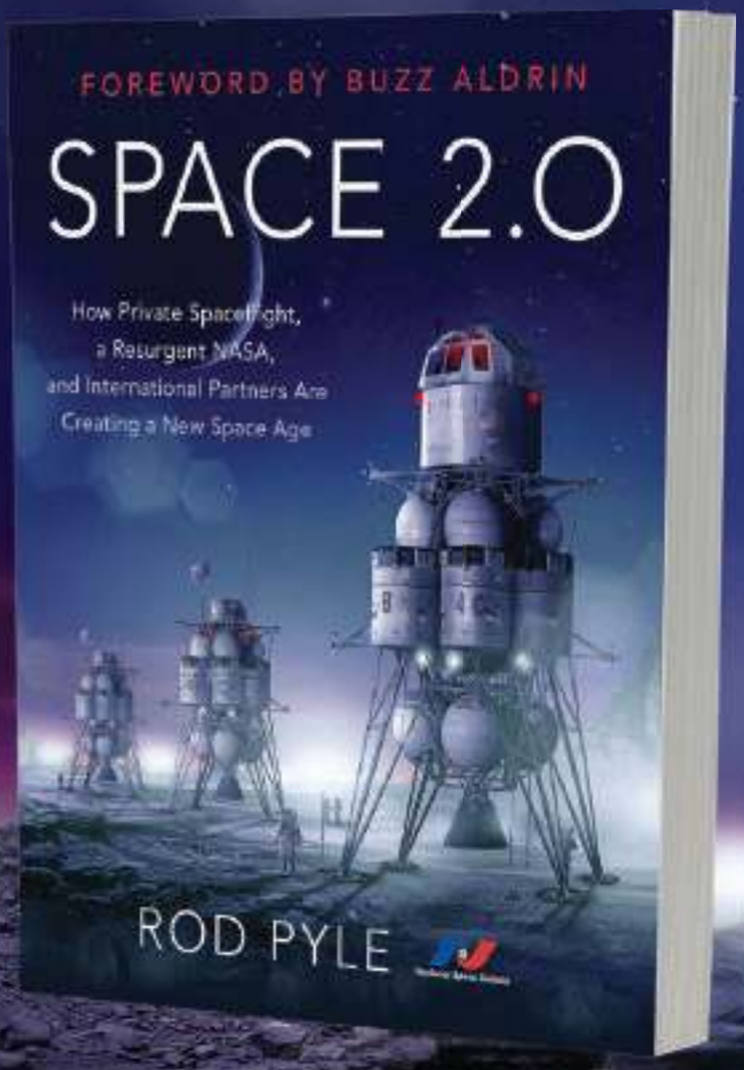
—GEOFFREY NOTKIN, member of the board of governors for the National Space Society and Emmy Award-winning host of *Meteorite Men* and *STEM Journals*

"…a great read for those who already excited about our new future in space and a must read for those who do not yet get it. Buy one for yourself and two for loaning to your friends."

—GREG AUTRY, director of the University of Southern California's Commercial Spaceflight Initiative and former NASA White House Liaison

"Optimistic, but not over-the-top so. Comprehensive, from accurate history to clearly outlined future prospects. Sensitive to the emerging realities of the global space enterprise. Well-written and nicely illustrated. In *Space 2.0*, Rod Pyle has given us an extremely useful overview of what he calls 'a new space age'."

—JOHN LOGSDON, professor emeritus at Space Policy Institute, George Washington University



IN *SPACE 2.0*, SPACE HISTORIAN ROD PYLE, in collaboration with the National Space Society, will give you an inside look at the next few decades of spaceflight and long-term plans for exploration, utilization, and settlement. Speaking with key leaders of the latest space programs and innovations, Pyle shares the excitement and promise of this new era of exploration and economic development. From NASA and the Russian space agency Roscosmos, to emerging leaders in the private sector such as SpaceX, Blue Origin, Moon Express, Virgin Galactic, and many others, *Space 2.0* examines the new partnerships that are revolutionizing spaceflight and changing the way we reach for the stars.

LEARN MORE: BIT.LY/RODPYLEBOOK

THE YEAR OF APOLLO

Rod Pyle, Ad Astra Editor-in-Chief

As I certainly need not tell you, this year marks a half-century since the landing of Apollo 11 on the Moon, surely the most impressive and important peacetime accomplishment of the 20th century. This is something to celebrate, and media outlets across the country and around the world are creating Apollo 11 commemorative articles, books, television specials, and other content to mark the occasion (disclaimer: I will have three books on the subject out this year alone, one new and two in reprint). This reliving of history is good for the country and people everywhere who may be inspired to pursue scientific or technical careers.

It should be noted, however, that this is not just the 50th anniversary of Apollo 11. The year 2018 marked the beginning of a five-year observance of the accomplishments of the Space Age, and America's commitment to fulfill the goal put forth by President Kennedy in 1961 "to land a man on the Moon and return him safely to the Earth." This mandate was completed via multiple flights by a variety of crews from 1968 through 1972, and we should remember and laud everyone involved: the primary and backup crews, NASA management, the agency's labor force, and the nearly half-million men and women across the country that made the Apollo program such an incredible success.

This issue of "Ad Astra" is intended to do just that. While we have focused on Apollo 11 for its 50th anniversary, I have selected a variety of stories and images that look at the missions that preceded the first lunar landing, as well as the surrounding people and circumstances (such as the uncrewed Zond lunar flyby missions of the Soviet Union) that set the stage.

While Neil Armstrong was in fact the first human to set foot on the surface of the Moon, he and Buzz Aldrin, an NSS Governor, landed on the lunar surface at the same moment. They trained, flew, and succeeded together, supported by Mike Collins, the Command Module Pilot for their mission. Likewise, the crew of Apollo 11 was preceded by the crews of Apollo 1, killed in a launch pad fire in 1967; Apollo 7, the first to test the Command and Service Module; Apollo 8, the first to orbit the Moon; Apollo 9, the first crewed test of the Lunar Module; and Apollo 10, the first test of the Lunar Module (and its staging maneuver) in lunar orbit. These flights and their crews helped to assure mission success for Apollo 11.

Perhaps the best summary of the achievements of the Apollo era I've heard occurred during the completion of a 2005 interview with Apollo Flight Director Gene Kranz for an episode of the History Channel's "Modern Marvels" I was producing. I asked him if he had any final comments. Usually, after being peppered with questions for an hour or two, interviewees just shrug and say that's about it, but not Gene. He pursed his lips, looked at the floor for a moment as he gathered his thoughts, and then fixed me in that steely-eyed missile-man stare of his and said, "What America will dare, America can do." On this 50th anniversary of the first lunar landing, I'd like paraphrase that statement: what humanity will dare, we can do together. Happy anniversary, Apollo.

The NSS supports the embodiment of these ideals as humanity explores the solar system and settles space and nearby worlds.

A Message FROM THE Incoming Chair of the NSS Executive Committee

Dale Skran, Chair of the Executive Committee

The NSS recently held officer elections. Please join me in congratulating all who were re-elected, as well as our newly elected officers:

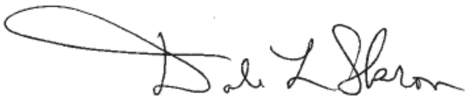
- Karlton Johnson – Chair of the Board of Governors
- Geoffrey Notkin – President
- Alfred Anzaldua – Executive Vice President
- Larry Ahearn – Vice President, Chapters

I would like to thank Hugh Downs, Chair Emeritus of the Board of Governors, and Mark Hopkins, the previous Chair of the Executive Committee, who over many years have led the NSS to new levels of success. As Chair Emeritus, Mark will lead several exciting new projects.

During the week of March 10th, I participated in our annual March Storm Washington, D.C. blitz. This effort is led by our D.C. representative, Aaron Oesterle, and the NSS's influence there is on the rise. An exciting current new development is that our draft language making space development and settlement a permanent part of the fundamental NASA charter has been introduced in the Senate by the bi-partisan team of Senator Peters (D-MI) and Senator Cornyn (R-TX) as S.584 (see link below). This key milestone is a direct result of our decision last fall to hire Aaron jointly with the Waypaver Foundation as our D.C. representative. Having a person on the ground there on a day-to-day basis will greatly amplify our extremely important twice-yearly Congressional events, March Storm and August Blitz/Fall Fury. The progress made to date speaks for itself. I would like to congratulate Ian Burell, a student at Virginia Tech University who served as this year's March Storm Advocacy Coordinator, on a job well done, and thank the many other volunteers and donors who actively supported this event.

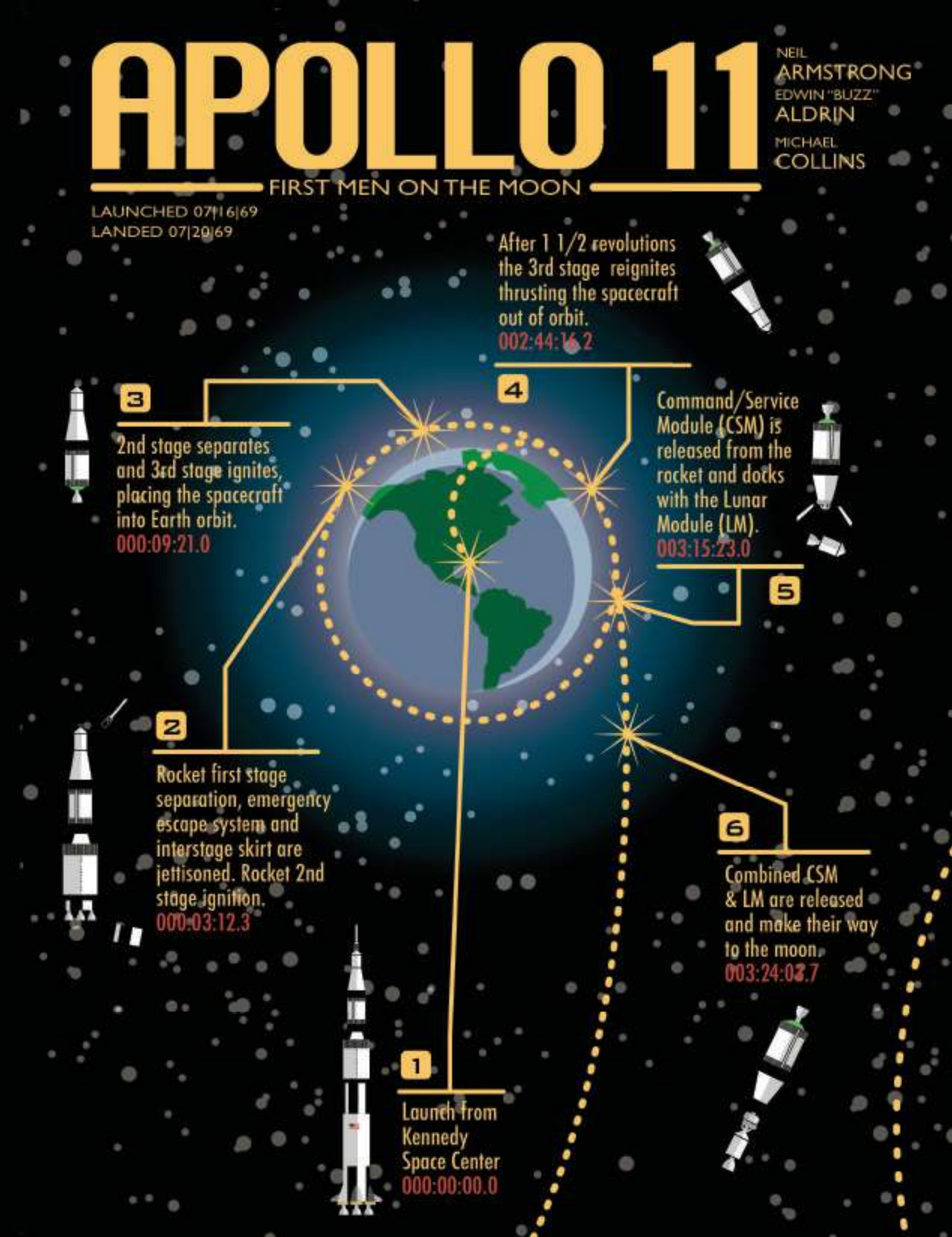
I thank you all for your support, both in the past as Executive Vice President and Chair of the Policy Committee, and in my new role as Chair of the Executive Committee. I look forward to working with all NSS members to build our future in space.

Ad Astra,

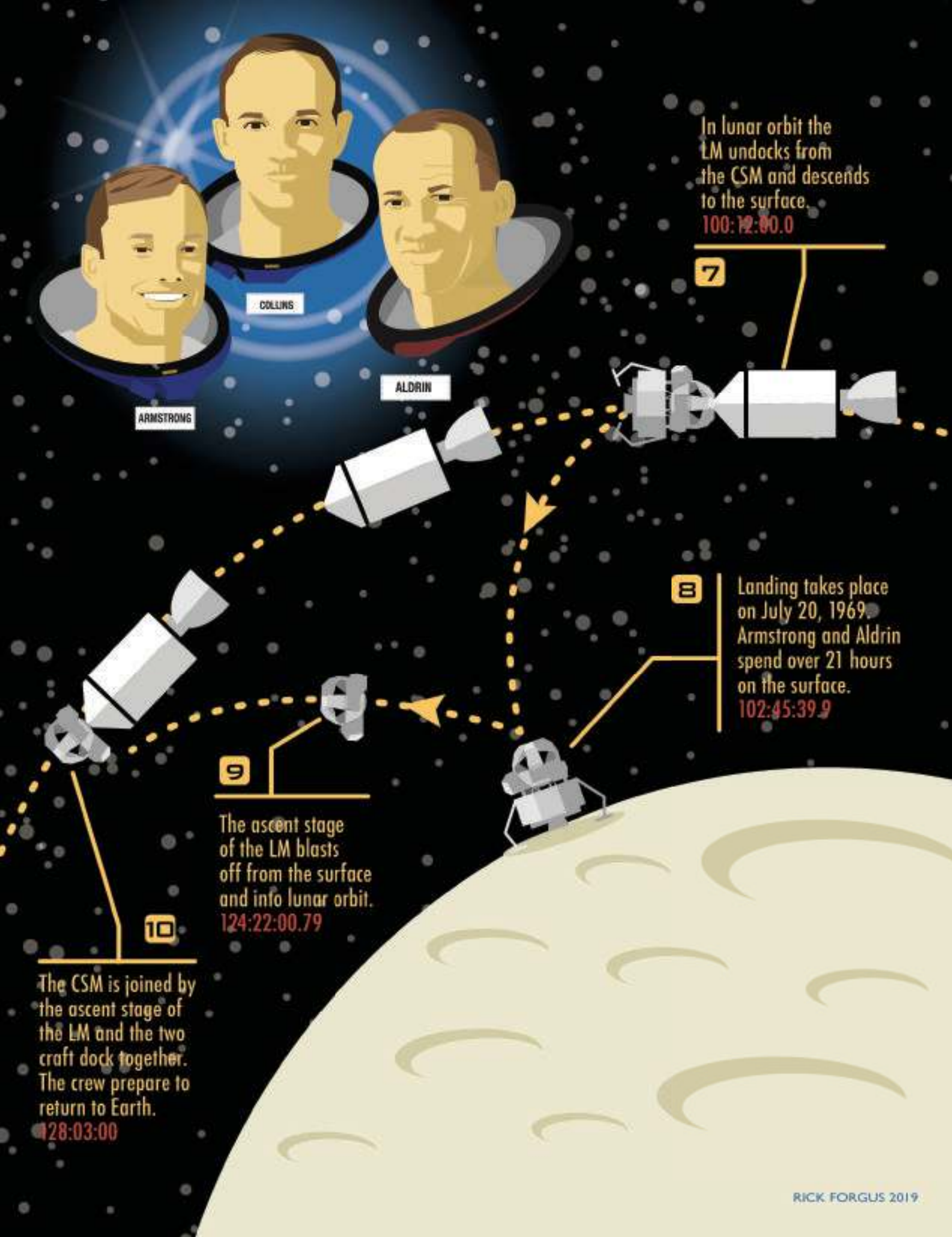


For more information:

- NSS Officers: space.nss.org/national-space-society-executive-committee-officers
- Draft language for S. 584: congress.gov/bill/116th-congress/senate-bill/584



APOLLO 11
FIRST MEN ON THE MOON
NEIL ARMSTRONG
EDWIN "BUZZ" ALDRIN
MICHAEL COLLINS
LAUNCHED 07|16|69
LANDED 07|20|69
1
Launch from Kennedy Space Center
000:00:00.0
2
Rocket first stage separation, emergency escape system and interstage skirt are jettisoned. Rocket 2nd stage ignition.
000:03:12.3
3
2nd stage separates and 3rd stage ignites, placing the spacecraft into Earth orbit.
000:09:21.0
4
After 1 1/2 revolutions the 3rd stage reignites thrusting the spacecraft out of orbit.
002:44:16.2
5
Command/Service Module (CSM) is released from the rocket and docks with the Lunar Module (LM).
003:15:23.0
6
Combined CSM & LM are released and make their way to the moon.
003:24:03.7


COLLINS
ARMSTRONG
ALDRIN
In lunar orbit the LM undocks from the CSM and descends to the surface.
100:12:00.0
7
8
Landing takes place on July 20, 1969. Armstrong and Aldrin spend over 21 hours on the surface.
102:45:39.9
9
The ascent stage of the LM blasts off from the surface and into lunar orbit.
124:22:00.79
10
The CSM is joined by the ascent stage of the LM and the two craft dock together. The crew prepare to return to Earth.
128:03:00
RICK FORGUS 2019

MISSIONS TO THE MOON:

An Apollo reference in

AUGMENTED REALITY

To use this feature, please do the following:

1. DOWNLOAD

the Missions to the Moon app from:

www.apple.com/itunes

www.android.com/apps

and open it on your smart device.

2. AIM YOUR SMARTPHONE OR TABLET

at the following six pages and see the space race come to life!

APOLLO FACT SHEET

A memo from then-director of NASA's Space Task Group Robert Gilruth about Apollo. He outlines the basic post-LOR decisions regarding the spacecraft, some of the expected difficulties and planned modes of operation. Dated 1962, it was circulated at a time when Gemini was still being referred to as Mercury Mark II.

Apollo Dec 6 or Jan ca 1962

Spacecraft description

(12)

MANNED SPACECRAFT CENTER

FACT SHEET

APOLLO SPACECRAFT

Robert R. Gilruth

The Project Apollo spacecraft is a three-man vehicle being designed and constructed for this Country's initial expedition to the lunar surface. This lunar expedition has been made a National program under the direction of the National Aeronautics and Space Administration. The Apollo spacecraft is being specifically designed to be launched by the Saturn series of launch vehicles.

The NASA has assigned the management of the Apollo and Saturn programs to the Manned Spacecraft Center and the Marshall Space Flight Center, respectively. These centers will work closely together in the development of this flight hardware to assure complete compatibility and to optimize such compromises which must be made to settle the not unexpected design conflicts. This melding of programs has already begun. Some early Saturn flights which were initially assigned to the sole purpose of launch-vehicle development are scheduled to carry development and prototype versions of the Apollo spacecraft. These flights will not only materially aid in the Apollo development program but will also provide a means for assessing the complete system and the operational problem associated with it.

It is felt that a scheme of successive tests and missions, each of increased difficulty or complexity, is the best means of developing spacecraft for manned flight. This is the traditional method employed in prototype testing of aircraft and is also the method used in the Mercury project. This method is ideally suited to the Apollo spacecraft since it allows for manned flight on early missions of reduced hazard and is in keeping with the development of the Nation's launch vehicle capability. The Saturn C-1 will be suitable for earth-orbital missions. An advanced Saturn will carry the spacecraft to escape velocity and will be suitable for circumlunar and lunar-orbital flights. The lunar-landing mission may be made with some type of rendezvous scheme using Saturn launch vehicles or by the direct approach with a large launch vehicle.

The Apollo spacecraft will be primarily designed for its lunar mission. Nevertheless, it will be well suited for other missions. It will be capable of rendezvous and, therefore, should work well in support of orbital space stations and laboratories. It will be designed to provide adequate accommodations for a 14-day duration mission with the three-man crew. With only minor modifications, it should be able to carry double that number of men on flights of short duration.

SATURN V

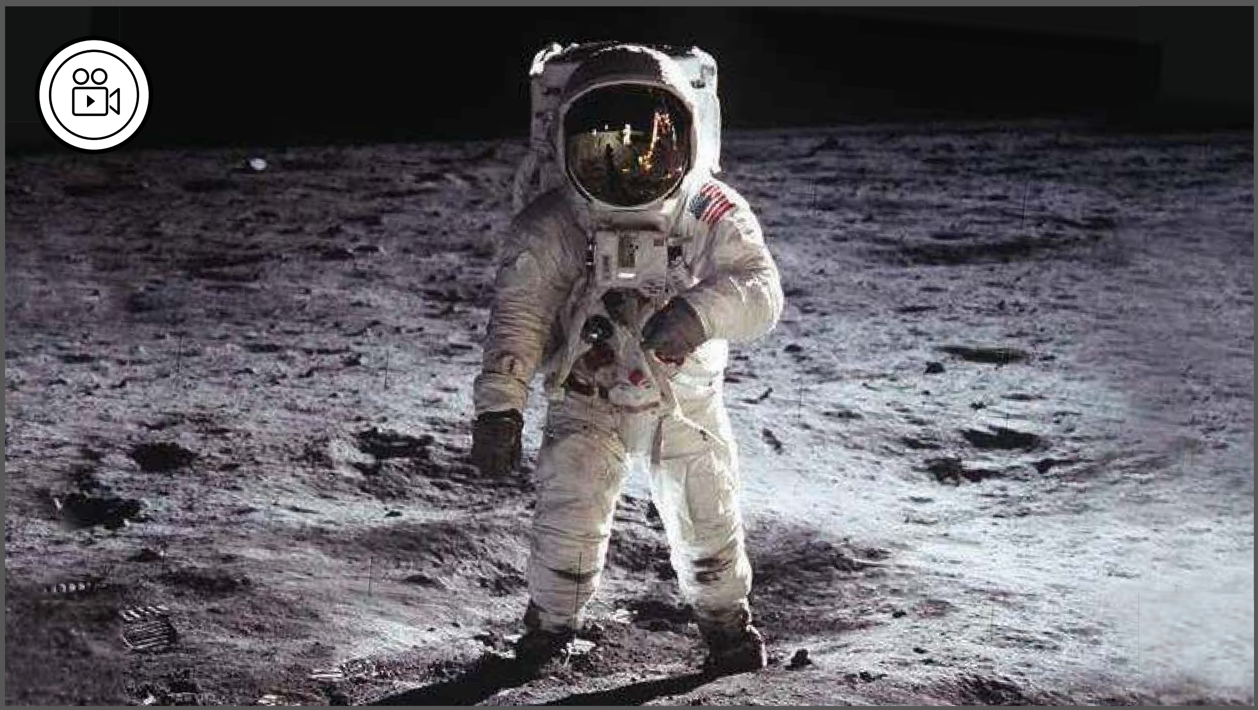
AP OLLO 11 LAUNCH

Below 16 July 1969: Apollo 11 blasts off from the Kennedy Space Center in Florida, seen here in an appropriately patriotic photo.

APOLLO 11 LANDING

Below The flags, cigars and cheers break the sanctity of Mission Control, Houston, when Apollo 11 lands. In the center is Chris Kraft, Director of Flight Operations.

ONE GIANT LEAP



THE APOLLO 11 MISSION REPORT

The Apollo 11 Mission Report was released in November 1969, three months after the triumphant first landing. Overall, the flight was rated as "excellent."


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 11

MANNED SPACECRAFT CENTER HOUSTON, TEXAS

Harmony of the Seas®

CELEBRATE APOLLO 11 ONBOARD HARMONY OF THE SEAS®

Join us for a journey from Caribbean waters to the Sea of Tranquility as we celebrate the 50th anniversary of the first footsteps on the Moon. Join NASA expert and spaceflight author Rod Pyle as he hosts Apollo astronauts and leaders from Mission Control for a stunning historical experience you'll remember for another 50 years. In between exploring seven floating neighborhoods packed with amazing, innovative and first-at-sea experiences. Sip cocktails crafted by a robot at Bionic Bar®. Savor reimagined rustic Italian by celebrity chef Jamie Oliver. And hand jive along to the hit Broadway musical Grease. Plus Island hop from Perfect Day at CocoCay to St. Maarten and beyond. This is not the Caribbean. This is the Royal Caribbean®.

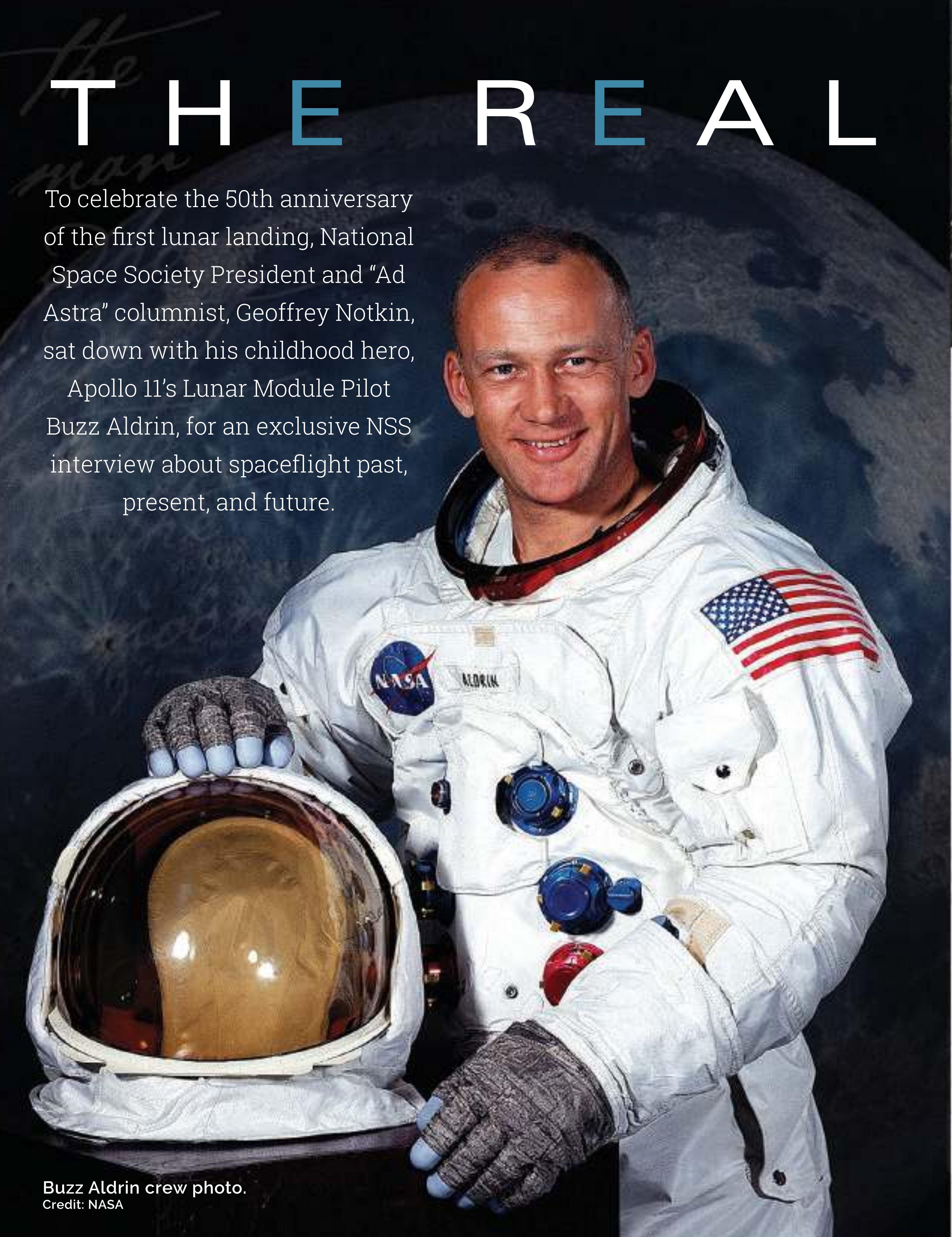
HARMONY OF THE SEAS

7-NIGHT EASTERN CARIBBEAN & PERFECT DAY

Departing January 26, 2020 | Sailing from Port Canaveral (Orlando), Florida

Perfect Day at CocoCay, The Bahamas • San Juan, Puerto Rico Philipsburg, St. Maarten

For more information about this cruise please call 949-727-1211.
To book, please contact Connection to Cruise at 888-798-9133.



THE REAL

To celebrate the 50th anniversary of the first lunar landing, National Space Society President and "Ad Astra" columnist, Geoffrey Notkin, sat down with his childhood hero, Apollo 11's Lunar Module Pilot Buzz Aldrin, for an exclusive NSS interview about spaceflight past, present, and future.

Buzz Aldrin crew photo.
Credit: NASA

BUZZ

Geoffrey Notkin


Credit: Michael Kirk

I sat beside Colonel Edwin Eugene Aldrin Jr.–known to the entire world as "Buzz"–at a large, round, elegant banquet table in the grand ballroom of the downtown Hyatt. Just the two of us.

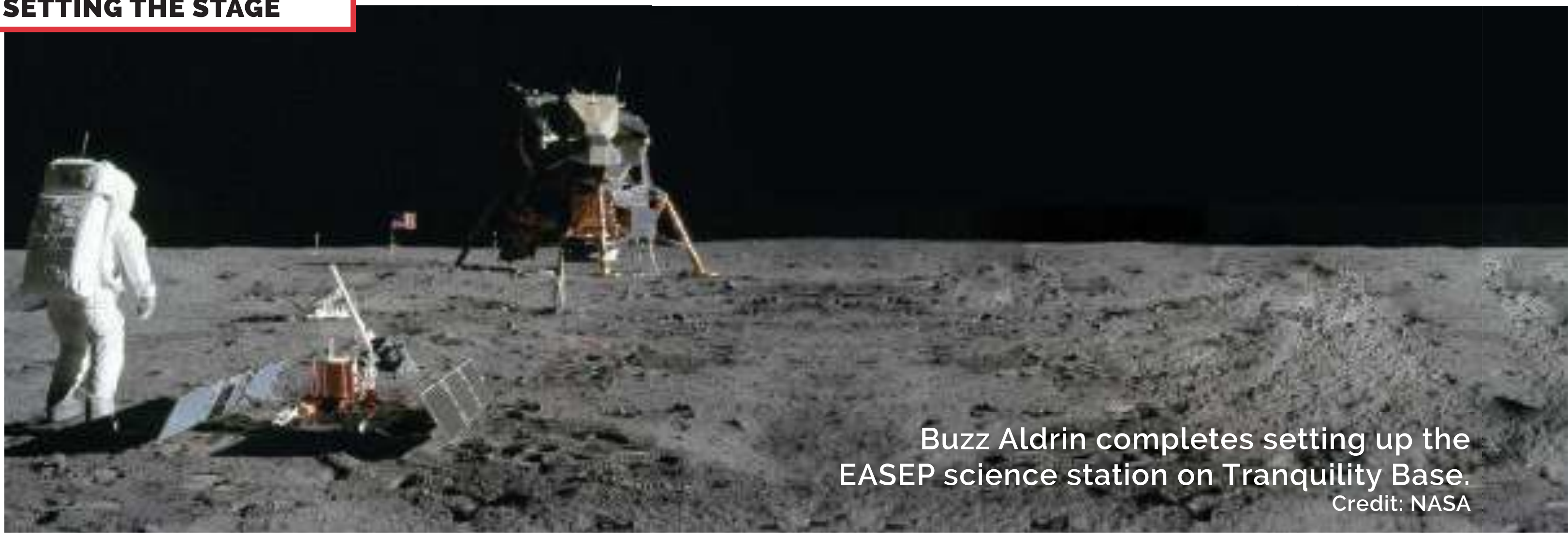
Our places were beautifully and meticulously set for the upcoming dinner. Aldrin would present the evening speech. I gave the address the previous evening and Aldrin had been seated right in front of me. No pressure there. Now, the tables surrounding us had no occupants; their perfectly-aligned geometry reminding me of launch pads along the seaward side of Cape Canaveral. All sites perfectly prepared and awaiting the upcoming launch. Or dinner.

The ballroom lights were low and the big room nearly silent. Just the occasional soft clink as a server fine-tuned the alignment of a wine glass or a dessert spoon. As a career performing artist, I have always been fascinated by the hush, the lull, the expectant silence that exists before the show. We, the performers, are like fairies, tiptoeing quietly and respectfully, lest some misstep should accidentally jinx the upcoming performance.

On our table lay pages of notes; my notes. I would introduce Buzz Aldrin before his much-anticipated conference keynote, and I would give it my all. I had worked on those notes for hours; it isn't every day you get to honor a boyhood hero in a venue packed with astronauts, engineers, and spaceflight professionals. I wanted to make mission-critical certain that my presentation was the best it could be. That being said, it was, in a sense, a complete redundancy, because you could hardly be a guest at that dinner and not already know who Aldrin was.

"Is there anything in particular you'd like me to mention, or not mention?" I asked him. He handed me a "Let's Get to Mars" t-shirt, which I now only wear on special occasions. "The main thing," he instructed, "is don't cut into my time. I have a lot to get through."

I looked at my multi-page speech, spread out on the fancy tablecloth. "I'm



Buzz Aldrin completes setting up the EASEP science station on Tranquility Base.
Credit: NASA

glad you said that, because I'm a talker." I was joking and laughed to underline it, perhaps slightly shy in the presence of a living legend. "I know," he chuckled. "I saw your talk last night."

Amused and somewhat discombobulated by this, I excused myself from the colonel, found another emptier and even quieter table and—with just minutes remaining until showtime—trashed half of my speech; because when a man who went to the Moon tells you to keep it short, you don't get wordy.

"The NSS really has a broad appeal and should have a bigger presence. The question is: what is a good way to engage with people, especially young people, who are interested in space but who know just a bit about us, or don't."

The keynote went well. I entertained the audience; Aldrin entranced them.

Some years later, I had the opportunity to conduct my own interview with Aldrin for the NSS. When he strode into the plush Los Angeles interview room, wearing a deliciously loud t-shirt depicting a flag-wielding astronaut and a flying eagle, topped by stars and stripes suspenders, I was once again struck by the vigor of this man in his late eighties.

There is an energy about him; something substantial yet melancholic. Perhaps "gravitas" is the best word. It's so obvious that it seems almost trite to put it into written words, but Aldrin has the wistful eyes of someone who has seen indescribable things.

I asked him about the early days of the National Space Society: "When the National Space Institute was merged with the L5 society ... it brought a more national presence together with a regional one," he said. The National Space Institute (NSI) had been founded in 1974 by Wernher von Braun, and the L5 in 1975, inspired by the work of Gerard O'Neill. The two organizations joined in 1987 to become the National Space Society. "I became involved ... when Lori Garver asked me to be the Chairman of the NSS Board of Governors. She was the NSS executive director at the time. Garver served in this capacity from 1989 to 1998. There are a lot of organizations that have been a joy for me to be with, but the NSS is one that is available to all. It is serious and goes into a lot of different disciplines. The NSS helps spread the word, and not just to younger people. It's not just a society of people who've been there," Aldrin told me, smiling, as he pointed upwards. "This brings up what I hope comes out of the 'togetherness' of NSS – the exchange of ideas that stimulate."

"The NSS has since evolved into a broader human spaceflight initiative. You get a great reward from this—the number of people you get excited about space. That was the real purpose," he continued. "I think the NSS really has a broad appeal and should have a bigger presence. The question is: what is a good way to engage with people, especially young people, who are interested in space but who know just a bit about us, or don't."

Agreeing with this, I asked him about some future directions in which he might like to see the NSS, and broader space policy, move.

"I'm very interested in dealing with international groups. I've heard people discussing this over in China. 'How should we come together?' When I showed up, everybody joined together ... so I listened and I kept suggesting what they might share and I said, 'Have you ever thought of bringing together the capable nations to do something? Not everybody is capable of doing those things,'" he said.

"How might we do such things differently in the future?" I asked.

"If you're interested in doing things jointly—doing them together—it's best to compete at the design level. Pick the best design, then cooperate at the operational level where you carry things out."

The discussion had moved beyond the confines of the NSS and into NASA and the U.S., and I asked him to expand upon those thoughts.

"Right now, we have five space-capable nations: the U.S., Europe, Russia, Japan and China. The U.S. has the brains and the desire and the reputation to unify these countries in space efforts ... the Europeans have an agreement with the Russians to work together at the Moon, and the Europeans have astronauts that are learning Chinese. [The U.S.] wants to be involved with Japan."

I asked Aldrin what was his bottom line.

"It's very crucial to not have a competition with China. I think we've already seen that with Russia. We can work together..." he went on to discuss some of the benefits of this, then recast his thoughts toward the opposite outcome: "There are other pathways that may not be too beneficial for them or for us ... to start off international relations with a competitiveness in space is one of them," he said.

It has been oft remarked that it was fortuitous (or well-planned) that the first human to set foot on another celestial body was Neil Armstrong, a man well-known for his modestly and gentle nature. A different commander might, it has been speculated, have made it more about personal accomplishment and less about the mission, or the "We came in peace for all mankind" plaque left behind on the lunar surface. I think it should also be oft remarked that it was fortuitous (or well-planned) that the man who climbed down lunar module *Eagle's* ladder immediately after Armstrong was also uniquely suited—because of his ebullient personality and lust for life—to spend the following decades championing human spaceflight and exploration with unmatched zeal, longevity, and brilliance.

I asked for Aldrin's thoughts on how we might best achieve our shared goals in short order. He replied:

"The various backgrounds that diverse groups of people have when they come together and look at somebody else's problem are valuable. They can see that someone has been stuck in a rut about a specific problem, and may think of something by using what we call out-of-the-box thinking. That's a product of different backgrounds and different experiences and different cultural viewpoints. When we come together, we're better at problem-solving as an international group of thinkers."

I then asked if he was speaking specifically of China.

"In the Asian world, if somebody has been dominated by the memorization of things, or by rote learning, I want you to find a better way to do it. The exploration of alternate ways of doing things and making solid judgments, and then pursuing something, instead of having tunnel vision, gives you a freedom. And I think if there's anything important that you can do to inspire people, it's 'how can I look at what's being done without knowing how it got there?' Sometimes it helps to see the circuitous path, the path that got us to some result by doing something one way or another ... then, to look at alternatives and realize what inertia might be preventing us from looking at different ideas, better ideas. Pretty soon you're looking at the reasons why sometimes a country doesn't advance, because they get stuck in this bog of doing something a certain way because somebody wants to keep it just the way it is."

What about the current plans to return to the Moon first?

"Let's think about how we can use gravity and the absence of an atmosphere to our advantage on the Moon," he said with a sparkling smile. "I think we're going to find that out. It's not a place where, when you go there, it's so hard to get back that you're going to want to stay for a long time. Now Mars is a different case ... Back in the old days, we thought maybe we go to Mars for 20 days or 30 days, but that's very expensive. Go there at the wrong time and you only have a short time to stay. But if you go at the best time and you come back at the best time, you got about a year and a half and [you can stay] for six months, eight months depending on how you do it."

I asked Aldrin what, 50 years on, Apollo and the Cold War-era "Space Race" can teach us about future missions to Mars?

"Apollo was to be an advance of technology that we, this nation, were


Credit: Michael Kirk

behind. It became a 'race' because we put a destination into it. What we did when you really analyze it is: we sent two guys for one day. Two, three months later: two guys for one day. We had a little interruption that didn't quite work out [Apollo 13], so six, seven months later: two guys for one day. And we got a little bold, put a little mobility in it [the Lunar Rover] and we got two guys for three days. So, at the end, when the Vietnam War and other things ran us out of money, we had six out of seven successful launches and landings, and then back [to Earth] ... Nobody's been back since. Now that's a visit, and a very short visit, and a long time in between. With Mars, you're going to have a much different situation. We can get all the things we need on the Moon, the critical things, so when we get to Mars we know what we're doing. There are ways of assuring this. We will have tested things so much, we'll know that they are going to work the first time."

The curriculum vitae of Aldrin's 80-plus years on Earth, and elsewhere, are widely published, as are the details of his air combat service during the Korean War, the Gemini and Apollo missions, his books, and his work with charities and foundations. Perhaps less known are his guest appearances on "Dancing with the Stars," "The Simpsons," and "Big Bang Theory," his 2016 expedition to Antarctica, his "Mission to Mars" fashion line, and his continuing and active service on the National Space Society's Board of Governors.

"It is now fifty years since the spectacular adventure of Apollo. Where would you like to have seen us fifty years after that?"

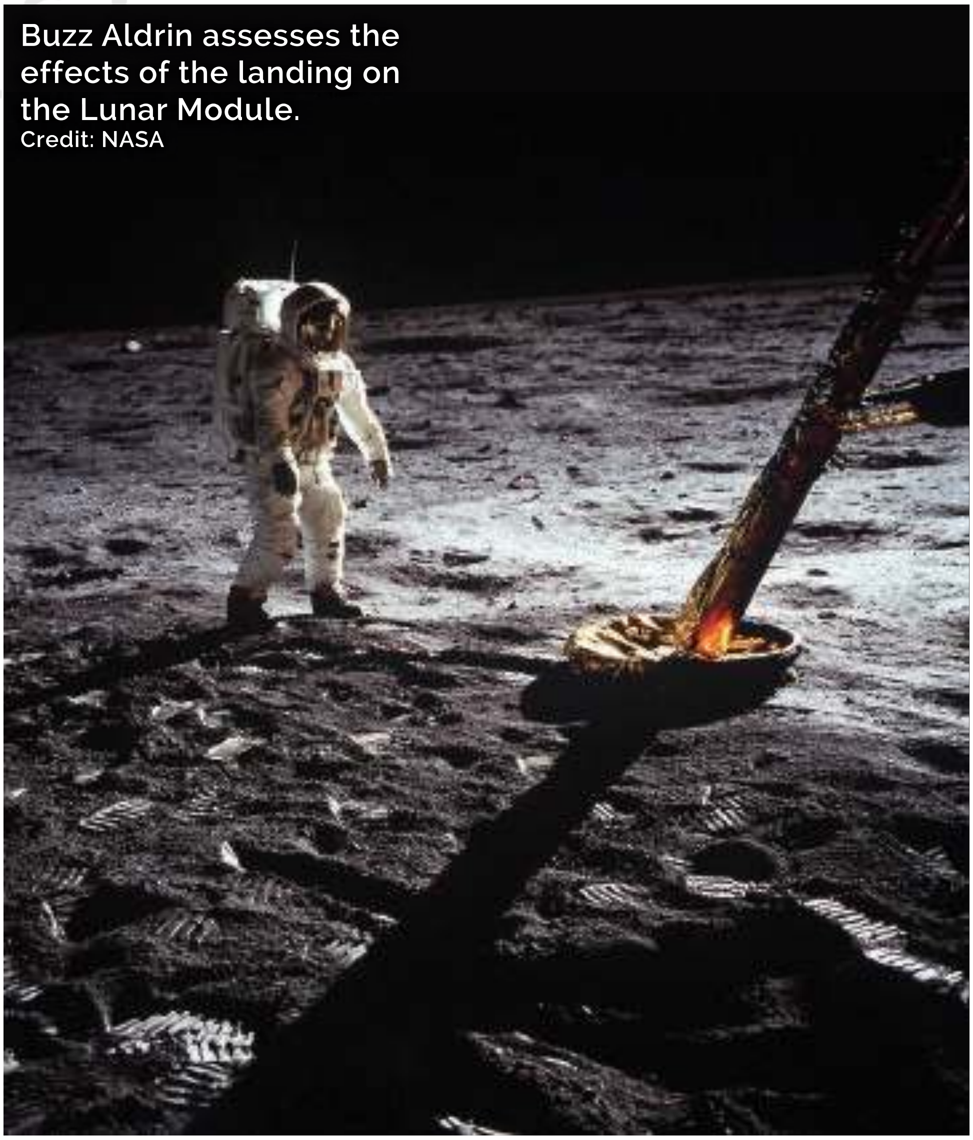
So much has been written about this pioneer of extraterrestrial travel that, when I introduced him in the ballroom that night, I wanted to—as I do now—avoid repeating statistics that have been so many times repeated, for fear that such repetition may, in time, make his accomplishments seem less remarkable. Such a thing cannot be allowed, because none of it is less than remarkable.

After a full hour in which Aldrin remained bright, focused, and full of ideas, I asked for a final comment.

"It is now 50 years since the spectacular adventure of Apollo," he said, looking deeply thoughtful. "Where would you like to have seen us 50 years after that?"

A year or two back, my answer to his question would have been: "Much further than we are now." But recently, we have witnessed magnificent achievements by SpaceX, Blue Origin, and Virgin Galactic, the building of the Stratolaunch aircraft, the opening of the Tucson Spaceport spearheaded by World View, and so much more—accomplishments that seem to be made of the glittering dreams of science fiction. A year or two ago, I might have said we should have been bolder, and more daring. But now, at last, we are on the way again.

Going there and staying is and always has been the goal of the NSS, and Buzz Aldrin too. Because of Aldrin's outspoken devotion to human spaceflight, he has been an integral and highly visible part of that mission—perhaps his most important mission of all.



Buzz Aldrin assesses the effects of the landing on the Lunar Module.
Credit: NASA

INSIDE

Neil Armstrong
Credit: James Vaughan

NEIL ARMSTRONG

JOHN F. KROSS PRESENTS AN EXCLUSIVE INTERVIEW WITH JAMES HANSEN, AUTHOR OF "FIRST MAN"

James Hansen, to left, with Neil Armstrong.
Credit: James Hansen

Dr. James Hansen is Professor of History at Auburn University and an authority on the history of science and technology. "First Man," his best-selling biography of Neil Armstrong, has received major awards and is the basis of the Oscar-nominated film of the same name. "Ad Astra" sat down with Hansen to explore the life and career of the first man to walk on the Moon.

AD ASTRA: "First Man" is in itself a "first" in so many ways. Why do you think that Neil Armstrong agreed to an authorized biography after turning down so many previous offers?

HANSEN: I think it was just the right time for him. I know that [his family] ... was encouraging him [and] ... I think ... when he saw my previous books he knew that I would take his engineering seriously. I think the fact that I was an academic actually was in favor of having it done. Neil ... [had] been an academic himself at the University of Cincinnati, so I think it was just a combination of factors.

AD ASTRA: What features about Armstrong's background from growing up in Middle America during the 1930s and 1940s shaped the kind of person he became?

HANSEN: I believe it strongly did and certainly as a biographer I feel ... you really need to understand ... how he was raised and what kind of community he was in. I think it was just a sense of togetherness and Americana, and also ambition to some extent. The kind of values that were rooted in small town community life ... that translated in some interesting ways for personality development and that ... seemed to lead in a direction for achievement.

AD ASTRA: You spent a lot of time with Armstrong. Can you give us some insight into his personality? He often came across as introspective and reticent.

HANSEN: Both of those characteristics are true, but at the same time he could be very social, had such a great dry sense of humor, and was just a lot of fun to be around. I think once you had found his comfort zone ... Neil came out of the shell in a lot of ways, whereas in public he [was] ... more cautious and circumscribed in his personality. What really impressed me the most was ... that once he gave me the go-ahead with the book, he trusted me ... and he didn't try to ... control the contents, the tone, or anything.

AD ASTRA: Do you think Armstrong was uniquely qualified among the astronauts because of his X-15 experience?

HANSEN: I think he was. A lot of people have commented on the fact that Neil was the only one that had any experience in a rocket-powered vehicle ... and all the other test flying that he had done in so many different types of vehicles when he was in NACA and a NASA test pilot. Of course, he had the military aviation experience too. He flew 70 combat missions in Korea and was in one of the first all-jet fighter squadrons with the Navy. Six of the seven Apollo commanders were naval aviators.

AD ASTRA: What was Armstrong's attitude about applying to be a NASA astronaut? Do you think he was ambivalent because of his late application? He had other options to fly in space, such as the X-20 Dyna-Soar.

HANSEN: He was very active in the X-15 program [and] had just been selected as an X-20 astronaut. I think he was ambivalent, and ... his application [to be a NASA astronaut] coming in late is certainly an indication of that. I do think that he wasn't sure that it was something that would be best for him. It was a tough time in the months after the death of his daughter in January of 1962. Putting all of that together and the late application ... does show an ambivalence on his part.

AD ASTRA: What were the other astronauts' opinions were of Armstrong?

HANSEN: The astronauts had a lot of respect for his intelligence and his mental approach to everything. As far as his reputation as a pilot, I think they had high regard for that as well. The only thing in terms of attitude towards Neil is ... that Buzz found him a little ... opaque. Neil was so quiet and kept so many things to himself that [Aldrin] ... didn't always understand exactly what he was thinking ... [but other] crew members were fine with that.

AD ASTRA: How were the crews selected for the Apollo missions after the Apollo 1 fire? Was Deke Slayton alone responsible for selecting the prime and the backup crews or were others involved?

HANSEN: Deke was certainly at the helm ... but Alan Shepard ... had some input on things, and I think that Deke also would have been in contact with probably [Robert] Gilruth and Chris Kraft some of the time as well. But I think in the end ... it was Deke's responsibility. Deke's approach ... was to find the best commanders and then get the crews lined up under them. He felt that ... any of the commanders could do any of the missions if they were trained up properly. There was nothing preordained from Deke or anybody else that [Armstrong was] going to be [on] the first landing crew. It just ... worked out that way, and Neil was always very clear about that. It was just a matter of circumstances.

"It was a private meeting between Deke and Neil [that] took place in a back room in Mission Control in Houston"

AD ASTRA: Given Slayton's informal rotation system and Armstrong's command of the E Mission backup crew, Armstrong must have been targeted to lead one of the early landing attempts.

HANSEN: I would agree with that. I think certainly looking ahead from that vantage point, a year and a half before the landing date, it would have looked like ... that could be the crew for sure. I think they were happy with that. I think they came away from Gemini [8 feeling that] Neil and David [Scott] handled that about as well as it could have possibly been handled. They also had a lot of confidence in Neil in terms of his professional demeanor. So to the extent that it looked like it was going to be Neil, I think that they were ... fine with that.

Armstrong prior to the flight of Gemini 8.
Credit: NASA

Armstrong at work in the X-15 prior to joining NASA.
Credit: NASA/US Air Force

AD ASTRA: Can you describe the meeting between Armstrong and Slayton during the flight of Apollo 8?

HANSEN: I think it was one of the ...revelations from my book because ... that meeting was never documented. It was a private meeting between Deke and Neil [that] took place in a back room in Mission Control in Houston. Deke ... told him ... that he would be commanding [Apollo] 11 ... if everything worked out with [Apollos] 8, 9, and 10. This was something that was kept ... between them. Slayton gave him the option of replacing Buzz on the crew with Jim Lovell. Neil asked Deke if he could ... think about it overnight. Neil ... came back the next day and ... told Slayton ... that Lovell deserved his own command and, secondly, that he was working okay with Buzz and there was no reason to change. If Neil had accepted that offer, then Lovell would have been with him on [Apollo] 11 for the landing. When I interviewed Lovell for the book ... he still knew nothing about it. This was something that Neil and Slayton had just kept to themselves all those years.

AD ASTRA: What factors were considered about who was going to be the first man on the Moon? Was the cockpit layout the real reason? You mentioned in your book that there was an informal meeting of Kraft, Low, Slayton, and Gilruth about Armstrong being the first one out.

HANSEN: That's the explanation that I stay with. I do believe that the rationale of the interior layout of the module [was] a smokescreen. I remember having a long conversation about this issue with Al Bean ... and he said ... "Look, if they wanted the Lunar Module Pilot to go out first ... you just don't suit up until you switch places." You could have ... swapped places, then put your

EVA backpack on. But … once you had landed and checked your systems … it makes sense for the commander to go out first. They knew that whoever went out first was going to be this global icon. They knew Neil's personality and they knew Buzz's personality, and they knew that Neil had no ego and could be trusted for almost any situation they put him in. That seems to me to be what was the clincher.

AD ASTRA: What about the phrase "Tranquility Base, the Eagle has landed"? Did Armstrong inform CAPCOM Charlie Duke that he was going to say that before the flight?

HANSEN: That's what Neil told me and what Charlie also confirmed, but it still obviously surprised Charlie a little bit when he heard it for the first time. When he hears it… it's at a very highly emotional moment, so [Duke] says … "Twanquility" and then he corrects himself to Tranquility. I don't think Buzz would have known … that's what Neil was going to say. Maybe Neil told him, but there was a lot of things Neil didn't tell Buzz until it happened, [including] President [Nixon's] phone call … on the lunar surface.

AD ASTRA: What about the origin of the phrase, "One small step for [a] man?" Did Armstrong reveal it to his brother prior to the flight?

HANSEN: I know his brother says that. I think it's baloney. We had quite a … discussion about that … and [Neil] denied saying it to anybody. In fact, he didn't even have the phrase composed until after the landing. I think he might have had the kernel of the idea … but he didn't have the phrasing down until after the landing.

Armstrong after landing the X-15. Note the tracks left on the dry lake bed surface behind the rocketplane.
Credit: NASA/US Air Force

Armstrong prepares to don his helmet prior to the launch of Apollo 11.
Credit: NASA

AD ASTRA: Was Armstrong confident of a successful landing throughout powered descent given the bad communication links, the 1201 and 1202 alarms, and the long terminal phase because of the craters and boulders?

HANSEN: The alarms were distractions. That's how he described them. Once he got down to a certain height above the surface, he was pretty confident that he had enough fuel to do what he needed to do. At a certain point, it becomes more dangerous to abort than to keep going. The machine was flying beautifully … and … he just had a lot of confidence that once they got down to a certain altitude, it was going to work.

I think Neil felt that he did as much as he humanly could. He wanted to keep contributing. He did do more than what a lot of people think.

AD ASTRA: Is it your impression that Armstrong would have flown the Lunar Module to a landing no matter what?

HANSEN: I do think … he was going to land it one way or the other. Gene Kranz … told me … that given Neil's personality it wasn't really clear … whether he agreed with all of the mission rules or not. He was again kind of opaque about things. I think Neil at a certain point just was committed to the landing and felt that … the machine was operating beautifully and he understood what needed to be done.

AD ASTRA: Did Thomas Paine, the NASA administrator at the time, promise to let the Apollo 11 crew fly the next landing attempt if their mission was not a success?

HANSEN: That's something that apparently did happen. They wanted to make sure that the astronauts didn't … push it too far. But I would be very surprised if they would have just turned the crew around. I think they would have gone to the next crew … or the backup. That's speculative.

AD ASTRA: Did Armstrong have any particularly memorable experiences while on the lunar surface?

HANSEN: Neil was very businesslike. He did make some … comments … that were nicely descriptive. I think he wanted to make sure that he described things well for the geologists. The most interesting thing from my point of view … is … this unscheduled visit over to the Little West Crater. It took a lot of effort to get over there. There is evidence from the telemetry … that his heart rate went up to over 160 getting there. The fact that Neil … did do something that wasn't planned because he thought it was worth doing, but then had to … hustle to get back to the Lunar Module. I think that's an interesting moment in the EVA.

AD ASTRA: What do you think about the scene in the movie where he leaves his daughter's bracelet at Little West Crater?

HANSEN: Somewhat ambivalent feelings, and I do speculate about this in the book. I talked to Neil, his sister, and Janet about it. We certainly don't know that he did it. There's no proof … but

... we're not sure exactly what he did take to the surface with him because the manifest for the PPK "Personal Preference Kit" ... [is] boxed up ... in the Purdue University archives and ... isn't supposed to be opened for another 20 years. When I did ask him ... if he took something of Karen's with him to the surface, his answer was sort of typically Armstrong. He said he didn't take anything for himself personally, which isn't really a ... direct answer. Honestly, if I went to the lunar surface ... I'd go nosing around over in the Little West Crater area because I'm not 100 percent certain that he didn't take something.

AD ASTRA: What's your opinion of the portrayal of Armstrong in the film? Did it capture all the facets of his personality, like his wry sense of humor?

HANSEN: I don't think it does, no, but at the same time, the vision of the director [was of] ... a whole series of very difficult episodes or moments that affect Neil pretty personally. Given the storyline ... and the focus on all of these losses and deaths that went along with ... this journey for Neil ... how do you want to portray him? You're not going to have him laughing. Actually, there are moments with him smiling ... or roughhousing ... with the boys so ... that element is there in the story. A couple of people have written things that say, "Well, this wasn't the Neil that I knew in the movie." [However,] they're not talking about the Neil that was living ... back in the 1960s. There are aspects of ... all of our stories that outsiders really don't know. Neil's personal story is what's going on in his marriage ... and between him and his sons. My book is able to talk about [that]. I found some things out ... that would not have shown up in "Life" magazine or a NASA publication. I just think there are certain things about the interior life ... of Armstrong that ... unless you look really, really closely, you wouldn't really know anything about.

AD ASTRA: Aldrin came off as somewhat of an enigma in the film. What were your impressions of the portrayal?

HANSEN: Well, I've had people tell me that Corey Stoll, the actor, and the dialogue for Buzz just nailed him 100 percent. Then there are others who say that, well, it came in really kind of unfair to Buzz. I have a lot of respect for Buzz as an astronaut, but I do think that personality-wise, there are some issues some of which he's been very honest with over the years. The editing ... maybe made it a little unfair by just focusing on those moments when Buzz says something ... but they aren't made up.

AD ASTRA: How did Armstrong see his role after the flight? Some have criticized him for not being more vocal in his support of the space program.

HANSEN: I think Neil felt that he did as much as he humanly could. He wanted to keep contributing. He did do more than what a lot of people think. People describe him as a recluse in his later years ... [but] that's badly mistaken because he did give a lot of talks. He just didn't give ... feature interviews ... because he figured it was just going to be more of the same. When Neil had something to say it was news ... and people paid a lot of attention to it. I think being rather judicious in his availability with the press was actually a good thing. [It preserved the] ... aura of the first man, which I think ... is still there.

AD ASTRA: In a BBC interview from 1970, Armstrong predicted permanent Moon colonies in our lifetime. Was he disappointed in the direction and pace of U.S. space policy?

HANSEN: I think he was, but at the same time ... he always took ... the long view of things. He understood ... that Apollo was ... pretty exceptional. It took ... a lot of extraordinary things coming together culturally, socially, economically, and politically in order for the Apollo program to really come to life ... but ... he felt there was an inevitability about our planet becoming a spacefaring civilization. I think he had a lot of confidence that it was going to happen at some point, and I never got a feeling that he was exasperated. He did ... speak to Congress with the cancellation of Orion [by the Obama administration].

AD ASTRA: Some of his statements were interpreted as criticism of commercial space or NewSpace.

HANSEN: He didn't believe that they were. There was a "60 Minutes" piece ... on Elon Musk ... [in which] CBS ... characterized Armstrong's position in his testimony as being against privatization. Armstrong ... was not against privatization. He was supportive of it, but ... he had ... concerns over closing down the shuttle program and not having anything ready to take American astronauts to space, and also ... that commercial space may not have the capital, the patience, or the ambition to be as careful about safety.

AD ASTRA: What do you believe Armstrong would think of NASA's current plans for the Lunar Gateway?

HANSEN: I'm not always confident I can predict now that he's gone ... but I'm not sure he'd be a big fan of the Gateway, honestly. I don't know that. It's just a guess. I do think he'd be ... more in favor of Moon Direct or whatever ... Robert Zubrin is talking about, without really needing Gateway. Neil would approach it as an engineer. In terms of the architecture of the space program ... he would have that thought out pretty carefully.

AD ASTRA: Whether by fate or design, can you think of a better representative than Armstrong to be the first man to walk on the Moon?

HANSEN: No, I really can't. I think he really represented it very well. The fact that his personality was as introverted and cerebral as it was ... enhanced ... some of the more ... iconic elements of it. He sort of remained an enigma to a lot of people. People could project meanings onto him that were not necessarily real. That makes for an even more iconic first man ... [but] it makes a first man that is more full of myth and legend and harder to see as a three dimensional human being. I don't think anybody could have done a better job. I don't think anybody could have become more mythological. I can't think of another astronaut ... that would have turned into the myth that Armstrong turned into because of the nature of his personality.

AD ASTRA: What do you think the NASA of today could learn from NASA in 1969?

HANSEN: I think one element of NASA and Apollo that I really admire ... were these famous "Tindallgram" memos [from] ... William Tindall, an engineer down at the Manned Spacecraft Center ... on issues that he thought were crucial to the success of Apollo. These memos would be circulated very broadly across the organization. They didn't get stuck within organizational structures. They crossed disciplines. They crossed organizations. I think NASA ... did it very, very well back in the 1960s, and I'm not sure in this day and age that it does it as well.

AD ASTRA: What about bureaucratic inertia and risk aversion in today's NASA?

HANSEN: Today ... you do get a sense that the bureaucracy is ramified to such an extent that it makes getting certain things done a little harder.

AD ASTRA: The next human flight to the Moon is EM-2, which is slated for 2022 at the earliest. Any thoughts about the cultural importance of someone who has living memory of deep space travel?

HANSEN: We've only got four Moonwalkers left and... it would be great to have that continuity. I have a lot of interest in the landing sites from the Apollo missions and their preservation. There's an organization called For All Moonkind ... and it's been active trying to get international resolutions through the U.N. not to spoil the Apollo landing sites. I do think they should be preserved as some sort of a world heritage site.

AD ASTRA: Do you think the commemoration of Apollo 12 could be lost in the afterglow of the Apollo 11 anniversary?

HANSEN: I hope it's not forgotten. I know there will be an anniversary celebration of some sort, but [the anniversary of Apollo] 11 ... may take all the air out of the room for any later anniversary events. [Apollo] 12 was a pretty incredible mission, had a great crew, and did a lot of interesting, important things. So, I hope that there are good memories for all of them.

AD ASTRA: What's the next project you're working on?

HANSEN: I am ... closing out my work on Armstrong by ... publishing two volumes of Neil's correspondence. I've selected a few hundred letters from the time of the landing through the end of his life [as a] good representation of the kinds of letters that he got from people all over the world. [In addition] there is a project I'm working [on] ... called "The Moon Rock Hunters." There are lots of Moon rocks that are missing ... and we're going to do a reality television series. It's not just going to be a fun show, but ... educational and ... [will possibly] recover some of the Moon rocks.

James Hansen's bestselling book "First Man" is available at most online booksellers and traditional bookstores nationwide.

Neil Armstrong crew photo.
Credit: NASA

SETTING THE

Landing humans on the Moon was an enormous undertaking. The massive Saturn V had to be designed, tested and tamed. The Lunar Module had to be developed from whole cloth, and many other machines and systems perfected before the first mission to the lunar surface could be successful. This is the story of that preparation.

Eagle on the Moon.
Credit: James Vaughan

STAGE

FIRST ACT of an EPIC LUNAR JOURNEY

John F. Kross

Three days after landing on the Moon, and with splashdown looming, the crew of Apollo 11 flicked on the television camera for a final broadcast from space. Taking turns before the lens, Armstrong, Aldrin, and Collins discussed the symbolic and practical aspects of their flight to a still Moon-struck world.

Then, in measured tones and barely suppressed emotion, the commander of Apollo 11 closed the broadcast by thanking the men and women who had labored for almost a decade to make the first lunar landing possible.

At its peak, the Apollo program employed 400,000 people and was supported by over 20,000 industrial firms and universities. They designed and built the spacecraft, composed the mission plans, and conducted the tests that led to Tranquility Base. That harnessing of energy and ingenuity represented the greatest surge in technological creativity and largest pledge of resources (about 107 billion in 2016 dollars) ever in peacetime. After six Mercury and ten Gemini flights, Apollo 1 finally stood poised on the launch pad in early 1967.

FIRE IN THE COCKPIT

On January 27, 1967, the Command and Service Module (CSM) for the first crewed Apollo mission—an Earth-orbiting flight—was perched on a Saturn 1B rocket at Launch Complex 34. Although liftoff was just a few weeks away, Apollo 1 (AS-204) had been a troubled spacecraft plagued by abraded wires, a leaky coolant system, and a faulty environmental control system. On Friday, January 27, the three-astronaut crew of Grissom, White, and Chaffee lay strapped in their couches for a "plugs-out" launch rehearsal. The hatch was bolted shut and the cabin pumped full of pure oxygen at 16.7 pounds per square inch (psi), two psi higher than sea level.

Communications problems delayed the test, but at 6:31 p.m. a shocking cry of "fire" echoed through the static. Seconds later, one of the astronauts yelled, "We've got a fire in the cockpit." There was a seven second pause, and then an anguished cry, "We've got a bad fire—let's get out ... We're burning up!" The crew struggled to open the hatch and technicians fought their way through flames and acrid smoke, but not in time. In moments, fire exploded onto the swing arm as the pressure vessel of the spacecraft ruptured. When technicians finally loosened the hatch, they

Gus Grissom, Ed White and Roger Chaffee were the three-astronaut crew slated to fly the first Apollo mission in early 1967. They lost their lives in a tragic fire on the launch pad.
Credit: NASA

felt only "heat and ashes." Later, the limp bodies of the crew were found still strapped in their charred couches.

In the wake of the tragedy, NASA convened the "AS-204 Accident Review Board" to investigate the root causes of the fire and to recommend corrective action. After a thorough enquiry, the board concluded that an "electric arc," probably from chafed wires in the left equipment bay, was the immediate cause of the inferno—which was fed by the pure oxygen atmosphere and flammable material in the cabin. But the board's 3,000-page report went further, blasting "deficiencies in design and engineering, manufacture, and quality control." An independent investigation by the U.S. Senate concluded that NASA's failure to report problems with the Apollo program was a "serious dereliction."

The fire was a serious setback to the program. Three astronauts were dead and landing on the Moon by the end of the decade was in doubt. However, the board's recommendations were painstakingly implemented, both material and managerial, and the Apollo spacecraft was redesigned. A new quick-opening hatch was installed, and flammable items were replaced with fire-resistant materials in accordance with the board's recommendation that "the amount and location of combustible materials ... be severely restricted." Wiring and electrical connectors were better insulated and protected, and the incendiary oxygen atmosphere was replaced with a nitrogen-oxygen mixture when on the ground and in early phases of flight. Stainless steel replaced aluminum junctions of the environmental control system. Astronauts were issued new fire-resistant spacesuits. George Low, Manager of the Apollo Spacecraft Program Office, was instrumental in approving and implementing the changes. "[He] brought order out of chaos [and] imposed an iron discipline on the program," explained astronaut Frank Borman.

More fundamentally, there were substantial changes in the management teams at NASA and the Command Module's manufacturer, North American Aviation. Adjustments in operating practices were also put into action promoting safety, coordination, and responsibility. Shocked by the fire, workers, inspectors, and management committed to greater diligence. Borman later reflected that the changes made in the wake of the fire contributed to the ultimate success of the Apollo program. "Out of terrible tragedy ... came the genesis of the Apollo program that was so successful," he said.

POGO STRIKES THE SATURN

Ultimately, the Apollo program would rise from the ashes, but time was running out. "A manned lunar landing by the end of 1969 depends on success in practically every one of the ... Saturn V flights ... in our operational plan," warned NASA administrator James Webb. The stakes were enormous on the morning of November 9, 1967, as the first of the mighty rockets stood poised on Pad 39A. At its base fumed five kerosene-LOX F-1 engines that together generated over 7.5 million pound-feet of thrust. The potential energy locked in its fuel tanks approached that of a small nuclear device. Historically, new rockets had been tested piecemeal, but budget cuts and the looming deadline forced NASA to abandon step-by-step flight testing. Instead, all three Saturn stages and the CSM would be tested "all up" on a single flight during the uncrewed Apollo 4 mission.

The Apollo 1 crew trains inside the Block 1 capsule.
Credit: NASA

At T minus zero, massive orange-white flames erupted from the base of the rocket. Seconds later, the roar of the F-1 engines washed over spectators

The launch of Apollo 4, the first flight of a Saturn V.
Credit: NASA

in staccato concussive waves. As it gained altitude, the rocket team's leader Wernher von Braun shouted, "Go, baby, go!" In the Press Center, news anchorman Walter Cronkite cried, "The roar is terrific," as the CBS press building shook around him. After a flight of eight hours and 40 minutes, the Command Module successfully splashed down northwest of Hawaii. Apollo 4 was a colossal gamble, but post-flight analysis showed nominal performance of the vehicle except for a thrust-axis vibration known as "pogo." Solving the pogo riddle would test the ingenuity of the Saturn engineers.

In general, pogo oscillation arises when g-forces push down on the fuel and oxidizer, creating a pressure surge in the engine's turbo pump and causing a momentary increase in thrust and rocket acceleration. However, the pressure surge also generates back pressure against incoming fuel and oxidizer, triggering a transitory reduction in pressure that sucks more fuel and oxidizer into the turbo pump, producing another surge. Pogo can also stem from fluctuating longitudinal velocity of the rocket motor or flexing fuel and oxidizer pipes. Regardless of origin, this longitudinal vibration can turn into a vicious cycle if it corresponds to the natural resonance frequency of the rocket's structure. In extreme scenarios, alternating positive and negative g-forces could rip the vehicle apart.

The amplitude of the oscillations on Apollo 4 were relatively small, but the second qualification flight of the Saturn V proved just how hazardous pogo could be. On April 4, 1968, Apollo 6 lifted off and arced beautifully over the Atlantic. However, the vehicle began shaking violently almost immediately as the F-1 engines of the first stage (S-IC) thrust toward orbit. After staging, one of the five cryogenic J-2 engines of the second stage (S-II) shut down early, and then a second engine quit. The remaining three J-2 engines burned longer to compensate for the lost thrust, but the rocket's troubles weren't over. The single J-2 engine on the third stage (S-IVB) fired but later failed to reignite in orbit. Houston signaled the Command and Service Module's (CSM) engine engine to burn for over seven minutes, sending the Apollo 6 spacecraft on a highly elliptical trajectory. Apollo 6 limped into orbit through the severe thrust oscillations that had nearly doomed the flight.

From the start, engineers suspected that severe pogo in the S-IC stage was related to the engine failures in the S-II and S-IVB stages. Detailed investigation traced the origin of the

Reducing mass was an ever-present goal of the Lunar Module's designers. The lunar lander was once described as 12 tons of propellant surrounded by four tons of "watchmaker's structure."
Credit: NASA

oscillation to the S-IC stage's cruciform thrust structure—one F-1 engine was located at each end and juncture of two I-beams, forming an "X." When the central F-1 engine fired, the unsupported center of the cruciform structure bent upward and then snapped back, causing the fuel line to compress and increase fuel flow. This was immediately followed by lengthening of the fuel line and reduction in fuel flow and thrust.

The resulting pogo-like movement ruptured the fuel lines that fed some of the J-2 engine's igniters. These devices were mounted in the J-2 engine's combustion chamber and fed by thin lines conveying liquid hydrogen and oxygen. Due to severe vibration, the hydrogen line feeding the engine igniter in one J-2 engine of the S-II stage ruptured, causing pure liquid oxygen to pour into the combustion chamber. The rocket's computer sensed a drop in pressure and commanded the engine to shut down, and then the other J-2 engine on the S-II stage stopped firing because it was cross wired to the first. The S-IVB stage used the same engine design, so a similar rupture in the engine igniter line was suspected.

The fix for this problem wasn't straightforward. Without time to redesign the engines, designers placed specially located bends in the J-2 igniter lines to absorb the oscillation, and then helium gas was pumped into the engine's liquid oxygen prevalves to dampen vibrations.

These fixes partially worked, but the next Saturn V flight, Apollo 8, still suffered from pogo in the second stage. Engineers then tried boosting the oxidizer tank pressure only to find pogo still troubling Apollo 9. Finally, technicians found the workaround of shutting down the center J-2 engine of the S-II stage early to avoid the worst of the oscillation. The other four engines would burn longer to make up for the loss of thrust. At last, the fix worked. There were close calls, notably with an F-1 engine failure on Apollo 13, but finally the astronauts were assured of a smoother ride to the Moon.

DELAYS TO THE LUNAR MODULE

Although the Saturn V represented an unprecedented engineering challenge, NASA was fortunate that its design had been adopted relatively early in the Apollo program. This was not the case with the Lunar Module (LM). The ungainly craft that would ferry two astronauts to the lunar surface was the last major piece of Apollo hardware to be designed and developed. Its start was partly delayed by NASA's indecision about the mission profile. Lunar Orbit Rendezvous, as opposed to Earth Orbit Rendezvous or simply landing the entire Apollo spacecraft to the lunar surface and returning it to Earth, wasn't chosen until mid-1962; more than a year after President Kennedy committed the nation to the Moon landing. Additionally, the LM's physical parameters weren't determined until 1963. Complicating the task, no one had experience designing vehicles to land on an alien world. Grumman Aircraft, the LM's manufacturer, was best known for stout naval aircraft built for carrier landings, not delicate spacecraft.

Weight and reliability were the key drivers of the Lunar Module program. The vehicle's size was restricted by the dimensions of the Saturn V's adapter section, while its weight was limited by the rocket's lifting capacity. The Saturn V could hurl 105,000 pounds to translunar injection, but the CSM weighed almost 65,000 pounds, CONT >>

The Lunar Module undergoes testing in low Earth orbit during the flight of Apollo 9 in March, 1969.
Credit: NASA

leaving only about 35,000 pounds for the fully fueled Lunar Module. The challenge was compounded since three-quarters of the LM's weight was propellant; each additional pound of hardware translated into four pounds of added weight. "We reached a point," said Joseph Gavin, Vice President of Space Systems at Grumman, "where we had to say, 'Look, we've got to stop the design … and squeeze some more weight out of it.'"

Grumman instituted a series of weight-saving measures that eliminated and re-engineered entire sections of the Lunar Module. Much of the outer skin of the LM was shaved to the thickness of a soft drink can, and some heavy cabin windows and the seats for the astronauts were removed. The landing gear was lightened because the vehicle would only function in the one-sixth gravity of the Moon. Likewise, the ladder was delicate—by Earth standards—and would buckle under the weight of a space-suited astronaut on Earth. In areas that only needed thermal protection, the descent stage was covered with a multi-layer thermal blanket made of aluminized Kapton and Mylar film. The LM's principle design engineer, Thomas Kelly, once said that the lunar landing craft was 12 tons of propellant surrounded by four tons of "watchmaker's structure" within a paper-thin fuselage and foil.

To make the LM as reliable as possible, engineers strove for simplicity and, whenever possible, duplication. The spacecraft had no pneumatic or hydraulic systems, and the ascent engine was simplified. Hypergolic fuel–chemicals that exploded on contact–was chosen because it did not require an igniter. A backup fuel injector system was installed in the ascent engine. But unexpected problems, including combustion instability, still cropped up and had to be resolved. Despite their best efforts, some items—like the ascent engine bell—represented a single point of potential failure.

Not until the beginning of 1968 was the Lunar Module set for its first uncrewed flight, designated Apollo 5. After launching on a Saturn 1B rocket, the module was put through a series of test firings of its ascent and descent engines, but onboard computer glitches caused premature shutdown of the descent engine on its first try. Overly conservative computer programs caused some misfires as well. The computer problems were fixed from the ground, and the LM's ascent stage engine was fired for six minutes until the fuel was exhausted.

Apollo managers considered the uncrewed test flight a qualified success. However, the next Lunar Module—assigned to Apollo 9—presented challenges from the moment it arrived at the Kennedy Space Center in June 1968. Electromagnetic interference plagued checkout tests, and faulty switches and a balky rendezvous radar vexed engineers. While the Saturn V and Command and Service Module were complete, it was clear the LM would not be flightworthy for months. Finally, in the spring of 1969, the LM was judged ready for crewed flights. Over a span of two months, successive LMs and CSMs flew around Earth (on Apollo 9) and around the Moon (on Apollo 10), each time boosted by the massive Saturn V.

Next up was Apollo 11 and Lunar Module 5, christened *Eagle*. It had taken eight years from presidential commitment to the first steps on the Moon, an amazingly brief span by any standard. The plans and spacecraft that placed astronauts on the lunar surface performed beyond any reasonable expectation. Some of those machines remain there today. They are a lasting tribute to the thousands who so tirelessly strove to make the Apollo program a reality, and should serve as inspiration for those who want to return to the Moon.

CHESLEY BONESTELL: A BRUSH WITH THE FUTURE

Directed and produced by Douglass Sterwart

Ad Astra staff

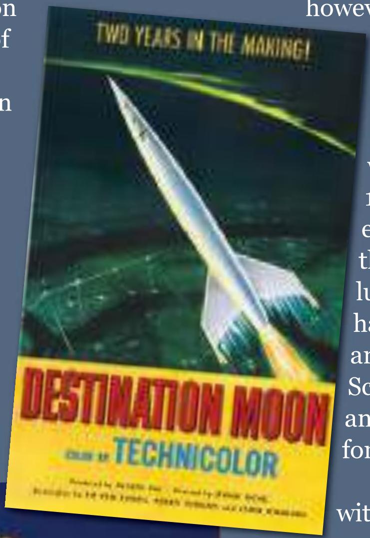
On this 50th anniversary of the first moonwalk, it's timely to discuss the pioneering artist who helped us get to the lunar surface—not with rocket science, but with a paintbrush. In the new documentary "Chesley Bonestell: A Brush with the Future," filmmakers shed light on a mysterious man who has been called "The Father of Space Art." Well before orbiting telescopes, satellites, and human missions into space, Chesley Bonestell took the American public on a journey through the solar system, beginning with a "Life" magazine article published in 1944.

The idea of space travel was not new, but Bonestell's realistic paintings of other worlds caused many to look up and think about venturing into the unknown. This was the first time that many people had seen representations of other-worldly landscapes.

One of his iconic masterpieces– "Saturn as Seen from Titan" (1944), appeared both in the "Life" magazine article and the 1949 book, "The Conquest of Space." Countless scientists and engineers were inspired to enter the fledgling aerospace industry by this painting.

Bonestell helped to design the Chrysler Building, worked on the Golden Gate bridge, and then became a special effects matte painter for movies like "Citizen Kane" and "The Fountainhead." Bonestell appears in the film through archival interviews captured and archived by NSS member Richard Dowling, who interviewed the artist in the 1980s. Twenty-four other individuals contribute on-camera commentary, some of whom knew Bonestell personally, and others who were profoundly influenced by him, including Ray Bradbury.

Bonestell's part in science-fiction movies like "Destination Moon" and "The War of the Worlds" is covered as well. When television came along, he created conceptual art for the 1959 series "Men Into Space." Although his Hollywood career was relatively short, Bonestell's contributions were long-lasting. Filmmaker Douglas Trumbull recounts an argument he had with director Stanley Kubrick during the making of "2001: A Space Odyssey." Trumbull was then in charge of visual effects. "At the time we were making '2001,' no one really knew what the lunar surface looked like," Trumbull explains. "Are these going to be craggy mountains like Chesley Bonestell was painting, or are these going to be low, rolling hills?" Trumbull argued for the latter, but Kubrick insisted that his Moon scenes should be "Bonestellian." When astronauts landed on the Moon in 1969, Trumbull was proved right.

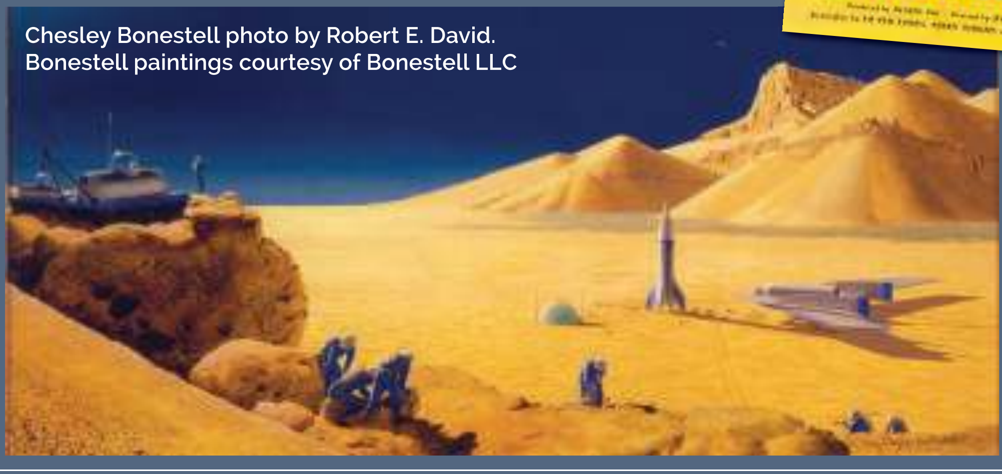


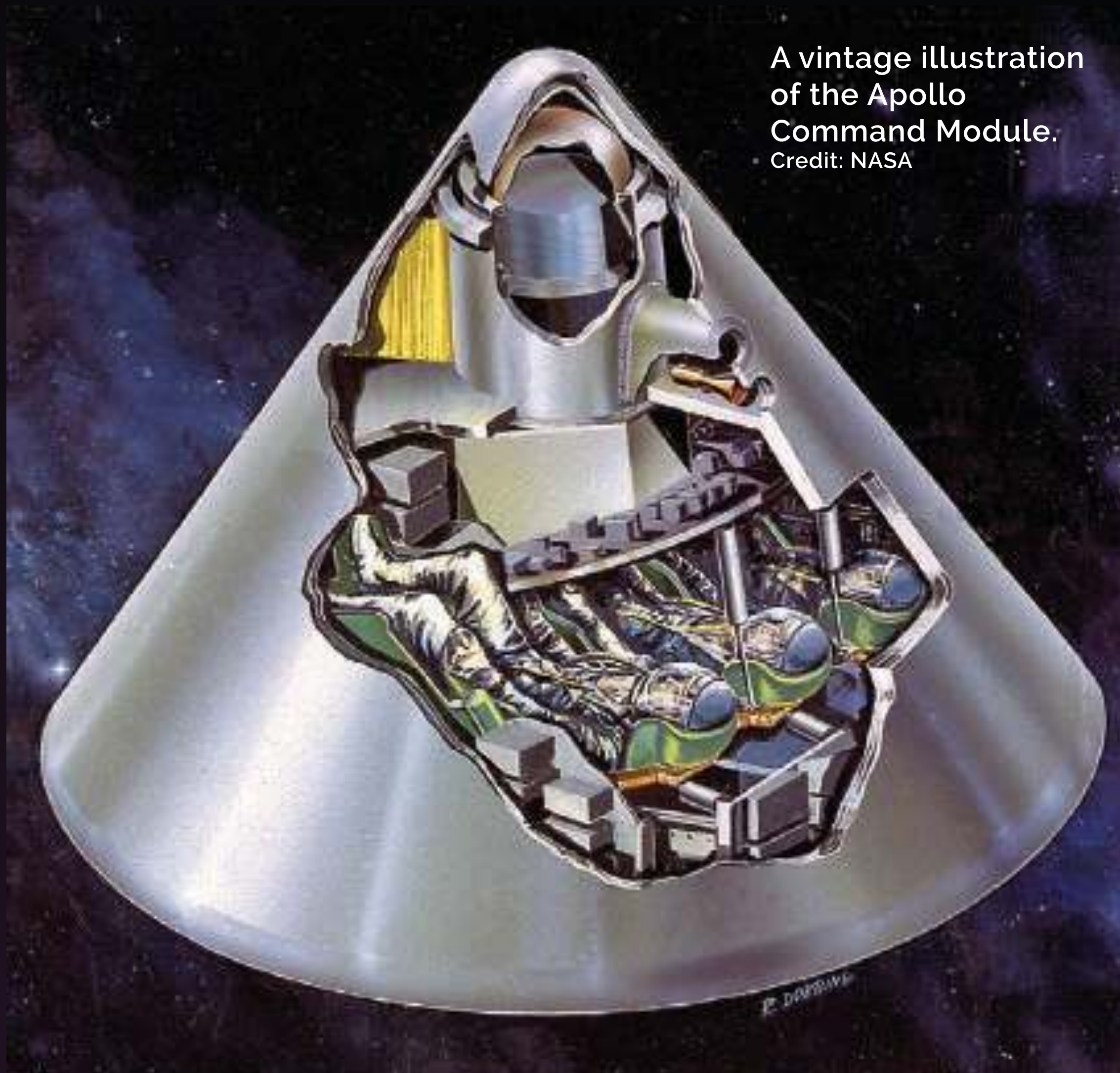
The lunar debate was not over yet, however. In 1957, Bonestell had painted a lunar mural for the Museum of Science in Boston, replete with craggy peaks. The exhibit was a hit with the public for years, but by 1969, was outdated. Bonestell expressed disappointment when the Moon landings revealed the lunar surface was not the way he had painted: "I was very much annoyed," when the Museum of Science took my painting down and sent it to the Smithsonian for storage in 1976," he said.

"Chesley Bonestell: A Brush with the Future" was recently screened at the Smithsonian's National Air and Space Museum. The film is the first documentary ever made about Bonestell, and it spans his 98 years in a mere 96 minutes. For Bonestell fans, and space enthusiasts, it's an overdue treat.

For more information about the film and where to see it, please visit the website at www.chesleybonestell.com

Chesley Bonestell photo by Robert E. David.
Bonestell paintings courtesy of Bonestell LLC





A vintage illustration of the Apollo Command Module.
Credit: NASA

A COMMANDING PRESENCE: The story of the APOLLO COMMAND MODULE

Jay Chladek

The Apollo Command Module was a critical component to the lunar missions, and the story of its development–including the tragic tale of Apollo 1–is central to understanding the story of the Apollo program.

Of the many incredible machines that took America to the Moon and won the space race, one that gets less attention than it should is the Apollo capsule, or in proper parlance, the Command and Service Module (CSM).

This workhorse spacecraft was often eclipsed in many of its accomplishments by its sibling, the Lunar Module, though the CSM did garner increased attention during troubled periods, such as the Apollo 1 fire and the Apollo 13 oxygen tank explosion. But it shined during the flights of Apollo 7 and 8, during which it flew alone.

The Command Module proceeded from concept to flight in only six years, an achievement as yet unmatched in spaceflight.

THE EARLY DAYS

The history of the Apollo program actually pre-dates President Kennedy's goal of "landing a man on the Moon and returning him safely to the Earth." Once Project Mercury was up and running, design studies began on a follow up "multi-mission" spacecraft. Mercury would get Americans into space, and the next vehicle would allow astronauts to live and work there. The original plan was for this new craft to expand NASA's capabilities in orbit. Over time the design project—now called Apollo—would evolve to allow astronauts to fly to lunar orbit and eventually land on the Moon's surface. Project Gemini wouldn't come along until 1961.

The spacecraft was designed around a crew of three, as it was felt that monitoring spacecraft systems would be a 24-hour job, with the astronauts operating in rotating shifts. The selection of a three-man crew dictated the size of the vehicle. NASA Langley engineer Maxime Faget, designer of the Mercury spacecraft, settled on a cone-shaped "blunt-body" design measuring nearly 13 feet (four meters) in diameter and 11-and-a-half feet (3.5 meters) tall. Internal living space was approximately 218 cubic feet (6.2 cubic meters); far roomier than the Mercury capsule. The shape of the Command Module (CM) and its offset center of gravity would allow the vehicle to generate lift during reentry and steer its course through the atmosphere, which would lessen the g-forces on the crew. Escape from the booster rocket in an emergency would be enabled by a set of small solid rockets suspended above the CM.

Below the CM sat the Service Module (SM), which contained fuel, a rocket motor, attitude control thrusters, and the consumables needed to keep the astronauts alive for their mission. Several configurations of internal hardware were considered before the SM began to resemble what we are familiar with today.

THE MOON, A MISSION FOR APOLLO

After President Kennedy took office in 1961, a lunar landing was chosen as a national goal, since it was thought that this challenge was sufficiently complex to level the playing field with the Soviet Union. At that point, Apollo was no longer a paper project. NASA began farming out study contracts to the private sector for how best to accomplish Kennedy's goal. Several of the major aerospace companies bid on the project and a number of them brought radical and innovative ideas to the table. In November 1961, NASA awarded a contract to North American Aviation to build the Apollo spacecraft, based on Faget's original design, and 30 other corporations signed on as sub-contractors to North American.

Before they could finalize a design, however, NASA had to pick a method by which to land humans on the Moon. Early plans envisioned a large descent stage under the CSM that would land tail-first on the Moon. It would depart Earth via either a single large rocket, or by using multiple launches of hardware that would be assembled in Earth orbit . In this design, the main engine in the Servce Module would be responsible for an ascent from the lunar surface.

Ultimately, neither approach was used. By late 1961, some in the aerospace community understood that landing something the size of a small ICBM on the Moon was going to be difficult and expensive, and would require a booster even larger than the massive Saturn V. It could be done, but not necessarily by the end of the 1960s. Eventually, a technique called Lunar Orbit Rendezvous (LOR) was selected, but this would require the development of a new spacecraft for the lunar landing, the Lunar Module (LM). The role of the Apollo CSM now shifted to carrying the crew from Earth to lunar orbit and back again.

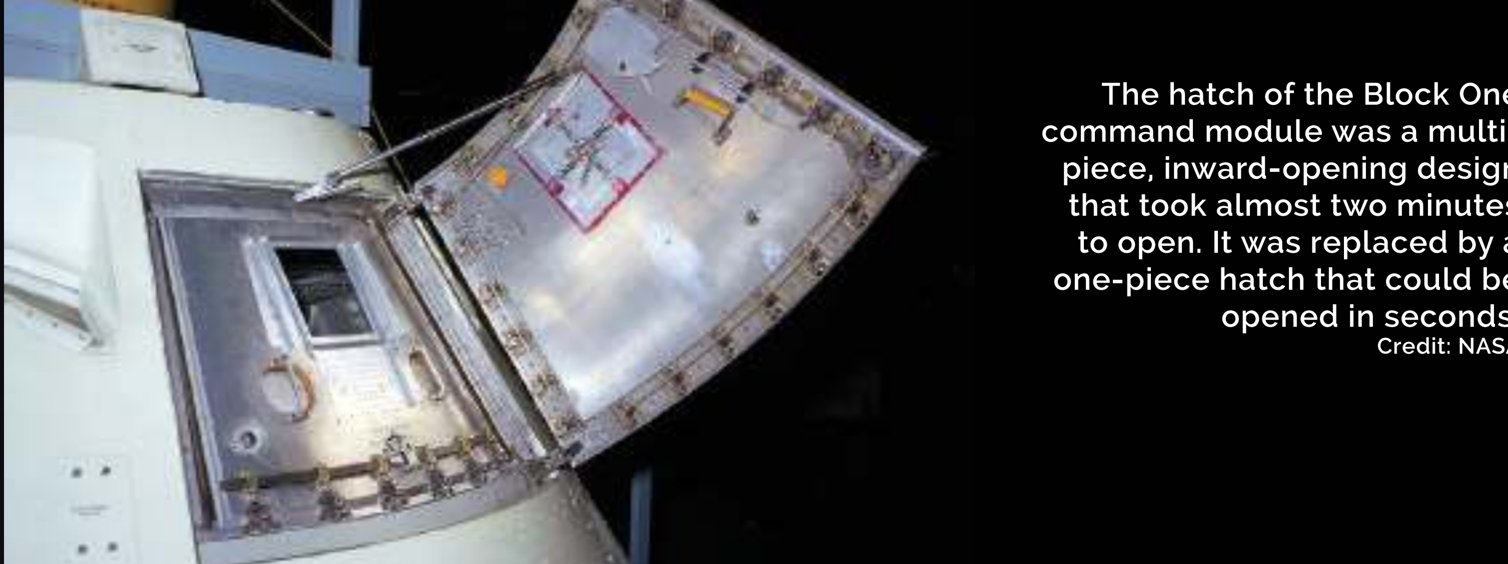
BUILDING "BLOCKS"

However, NASA and North American had already started work on the CSM before the decision to utilize a Lunar Module was made. The overall design was being tested for aerodynamics and recovery methods.

Changes came quickly as they refined the designs, and it wasn't uncommon for a machinist to make parts that were obsolete by the time he was done. This was in the era before computer aided design, and NASA's spacecraft were drawn by hand using paper, slide rules, drafting supplies, and a blend of engineering and art.

It would take approximately two years to build a complete Apollo CSM from the ground up and to assure that the spacecraft were going to be available for un-crewed test flights by the end of 1965, construction would have to begin before the end of 1963.

The Apollo 1 (AS-204) Command Module after the fire.
Credit: NASA



The hatch of the Block One command module was a multi-piece, inward-opening design that took almost two minutes to open. It was replaced by a one-piece hatch that could be opened in seconds.
Credit: NASA

With all the engineering changes, it was becoming clear that this would be impossible. Ultimately, it was decided to use the older, non-Lunar Orbit Rendezvous CSM design (known as Block One) for Earth orbit testing, and the Block Two spacecraft (which would be compatible with the LM) for the lunar flights, since these wouldn't be needed until 1968. A major difference between the two craft was the lack of a forward docking port on the nose of the Block One capsule, a holdover from the previous tail-first lunar lander design.

Block One CSMs were available for unmanned testing in very late 1965. One flew on a Little Joe II rocket (a small solid rocket booster) abort test of the launch escape system, and two flew sub-orbital missions in 1966 on Saturn 1B rockets. Things looked to be on track for the final mission utilizing a Block One craft, which would be the first crewed flight, later known as Apollo 1.

In late January 1967, the crew of Apollo 1 was conducting a dress rehearsal for launch when a fire broke out in the spacecraft. In a pure oxygen environment of over 15 pounds per square inch (psi), the fire burned out of control and toxic fumes asphyxiated astronauts Gus Grissom, Ed White, and Roger Chaffee in less than a minute. The crew couldn't get out due to a side hatch that opened inward, as the rising internal pressure of the cabin due to the fire made opening the hatch impossible.

APOLLO 1 MISUNDERSTOOD

It is often reported that this caused an 18 month delay in the program during which extensive changes were made to the spacecraft to help ensure the safety of the astronauts, but this is not entirely true. Early on, NASA planned to fly a few Earth orbital missions with the Block One spacecraft, but this number dropped as the Block Two craft evolved and only two manned missions with the Block One spacecraft were planned. The second Block One flight was to be commanded by Wally Schirra, but this mission was ultimately cancelled. Schirra, among others, thought it unnecessary to fly a spacecraft that was a technological dead end.

It is true that over 1,800 changes were made to the Command Module design after the fire. The most visible work involved replacing the inward-opening hatch with one that opened outward within a few seconds in the event of an emergency. The rest of the changes focused on reducing the amount of flammable material and exposed wiring harnesses in the crew cabin. At the time of the fire, many of the hardware problems with the Block One spacecraft were unique to the early design. An ongoing danger in all the designs, however, was the pure oxygen environment.

On the launch pad, the cabin was pressurized to just over 14.7 psi to positively seal the hatch, which fit like a champagne cork into the Block One capsule's hull. But at that pressure, normally non-flammable materials can burn furiously—even aluminum. NASA had decided early on to go with a pure oxygen environment to reduce the weight and complexity of the life support system, and in flight, the cabin pressure would be five pounds psi, resulting in far less risk of a catastrophic cabin fire in space.

After the Apollo 1 fire, an oxygen and nitrogen mixture would be used until after launch, with the crew breathing pure oxygen in their suits. Once the spacecraft was in orbit, it would switch to pure oxygen at five psi.

Two remaining Block One Command Modules were used for unmanned Saturn V test flights, and starting in 1968, from Apollo 7 onwards, the Block Two spacecraft was flown. It proved to be a robust piece of hardware, capable of taking on any task to which it was assigned.

APOLLO AND SKYLAB

For the Skylab program the Command and Service Module was altered again. For lunar flights, the CSM had been powered up for almost two weeks at a time, receiving continuous electrical power from three hydrogen-powered fuel cells. Skylab needed the CSM to deliver astronauts to the station, and then remain there on standby until the crew was ready to come home, up to 84 days later.

To accommodate this requirement, engineers removed one of the fuel cells and the associated cryogenic tanks, replacing them with storage batteries. Once docked, the remaining fuel cells would deliver power to Skylab until their hydrogen fuel supplies were used up. A storage tank was installed in the Service Module to collect waste water from the fuel cells. Then, before returning to Earth, the CSM would get its batteries topped off by Skylab's power supply. Fuel for the Service Module's main

engine was cut back while fuel for the maneuvering thrusters was doubled, and one side of the Command Module was painted white to aid in cooling.

An additional CSM was also modified for Skylab in case a disabled spacecraft required the crew to be rescued. This "rescue" spacecraft had crew couches for five astronauts. If it was needed, the craft would launch with a two-person crew, dock with a second Skylab port, and then return home with all five crewmembers. It was almost used when the CSM flown by the second Skylab crew developed fuel leaks in two of its four thruster banks, but was ultimately not needed and was later consigned to a museum.

APOLLO LIFEBOAT

The final flight of an Apollo CSM was the American half of the Apollo-Soyuz Test Project (ASTP), which docked with a Soviet Soyuz spacecraft in 1975. After that mission, there were no more flights of Apollo hardware as NASA's focus shifted to the space shuttle and a possible larger, modular space station.

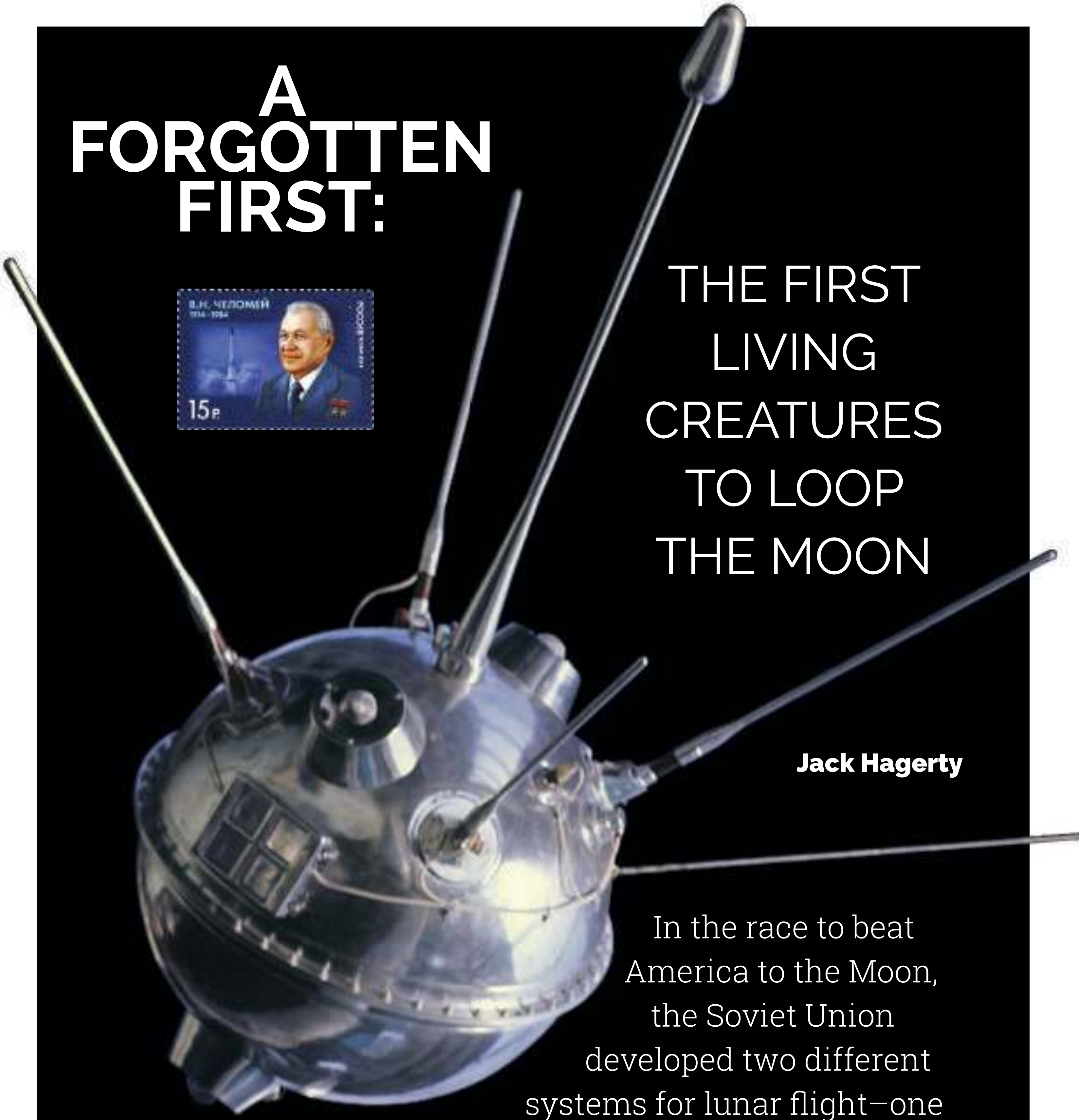
Nonetheless, the Apollo capsule was considered for other roles. The earliest proposal was to use the Command Module as an escape craft carried in the forward portion of the space shuttle's payload bay. The space shuttle was an untried design, and some within NASA questioned whether it could successfully return from orbit with its tile-based heat shield. Ultimately, the decision was made to not use a "rescue" Command Module, since even when stripped down the spacecraft was heavy, limiting the amount of useable payload a shuttle could carry.

Still later, designers studied the feasibility of refitting three Apollo capsules for use as lifeboats on Space Station Freedom, but the idea never left the drawing board. This concept was again revived in the early 2000s for the International Space Station, but since the Command Module was designed for an atmospheric pressure of five psi, while the station is pressurized at sea level pressure of about 14 psi, this was not deemed feasible—anything above seven psi would rupture an Apollo capsule while in the vacuum of space. The Command and Service Module slid gently into history.

Even though the remaining Apollo hardware has been relegated to museums, the shape and elements of the Command Module are strongly mirrored in the designs of NASA's Orion capsule, Boeing's Starliner, and even in SpaceX's Dragon spacecraft. These ships will carry the legacy of Apollo well into the future.

A FORGOTTEN FIRST:

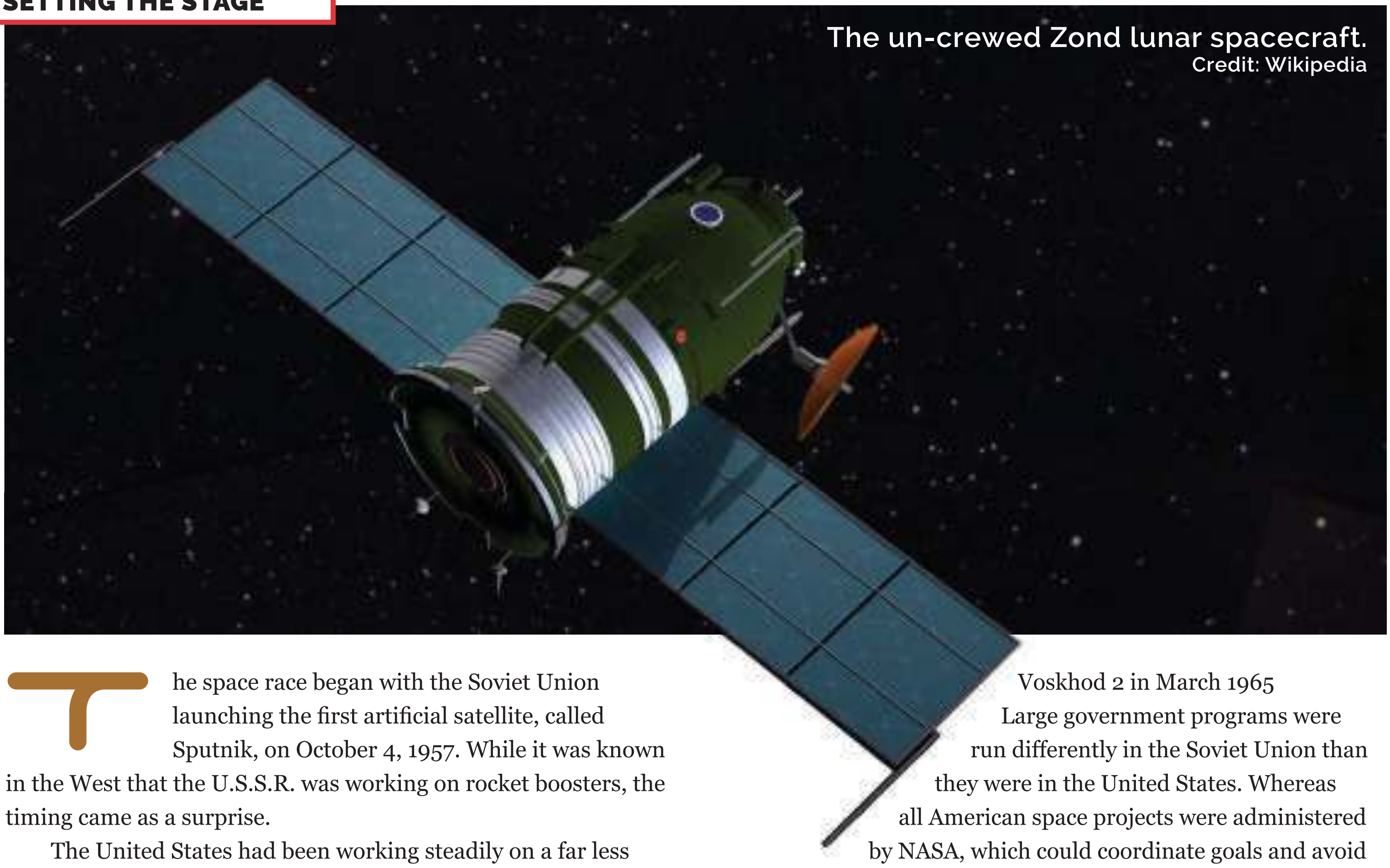
THE FIRST LIVING CREATURES TO LOOP THE MOON



Jack Hagerty

In the race to beat America to the Moon, the Soviet Union developed two different systems for lunar flight—one for landings, and another for lunar flybys. This story explains how the latter were successfully tested, but came too late to bring the Soviets glory in the space race.

The U.S.S.R.'s Luna 1 spacecraft.
Credit: Wikipedia



The un-crewed Zond lunar spacecraft.
Credit: Wikipedia

The space race began with the Soviet Union launching the first artificial satellite, called Sputnik, on October 4, 1957. While it was known in the West that the U.S.S.R. was working on rocket boosters, the timing came as a surprise.

The United States had been working steadily on a far less ambitious project called Vanguard, managed by the Navy. Vanguard was slow going; however, since President Eisenhower had insisted that the rocket be a "clean-sheet" design, the satellite would not be launched on the military booster then under development, the Atlas. Eisenhower wanted the Vanguard project, despite the Navy's involvement, to be clearly branded as a peaceful effort, and the rocket was being developed from scratch. It did eventually launch after a number of failed attempts, but by then Sputnik had soared into the heavens and shocked the world.

This performance was followed up by a number of Soviet space firsts, including:

- The first biological payload in orbit, the dog Laika, aboard Sputnik 2 in November 1957
- The first mission to leave Earth orbit, Luna 1, in January 1959 (it missed the Moon, which resulted in the probe becoming the first artificial object in orbit around the sun)
- The first mission to impact the Moon, Luna 2, in September 1959
- The first mission to photograph the far side of the Moon, Luna 3, in October 1959
- The first man in orbit, Yuri Gagarin, aboard Vostok 1 in April 1961
- The first simultaneous flights, Vostok 3 and Vostok 4, in August 1962
- The first woman in space, Valentina Tereshkova, aboard Vostok 6 in June 1963
- The first multi-crewed spacecraft, Voskhod 1, in October 1964
- The first spacewalk, performed by Alexi Leonov, aboard Voskhod 2 in March 1965

Large government programs were run differently in the Soviet Union than they were in the United States. Whereas all American space projects were administered by NASA, which could coordinate goals and avoid duplication, in the U.S.S.R. spaceflight was divided up among competing organizations called design bureaus, or OKB (the Russian acronym for Experimental Design Bureau). Each OKB was run by a "Chief Designer," and the most famous of these was OKB-1, which was run by Sergei Korolev. OKB-1 was responsible for every one of the firsts listed above. Since there was no economic competition in the Soviet Union, in theory the different OKBs competed for projects on their technical merits. In reality, projects went to the bureau with the best political connections and ability to manipulate the Soviet system. Since there was no coordinating agency like NASA, this meant that each OKB was fighting for itself, often to the detriment of the larger goal.

In the early 1960s, the Soviet Rocket and Space Technology Institute developed profiles for Russia's space-related endeavors. These included five types of increasingly ambitious crewed lunar missions:

- L1 – Lunar loop-around free return mission
- L2 – Lunar orbiting mission
- L3 – Lunar landing mission
- L4 – Extended lunar exploration mission
- L5 – Permanently-crewed lunar base

None of this mattered to the Soviet premier, Nikita Khrushchev. He saw the space program as a propaganda tool to demonstrate the superiority of the Soviet form of government. Even after Kennedy announced his intention to send astronauts to the lunar surface in 1961, there was no concerted Soviet Moon landing program for three more years. Instead, Khrushchev pushed for more space "firsts." By 1964, though, it was obvious that the only spectacular “first” remaining was an actual lunar landing, so he threw his considerable political weight behind the lunar program.

While Korolev had secured the L3 landing program for his OKB-1, Khrushchev knew that the initial flights of Korolev’s massive N-1 booster would take several years, during which there would be no additional firsts. To fill the gap, he diverted funds for the L3 program to Vladimir Chelomei’s competing OKB-52 bureau to develop a system for the L1 lunar flyby program. Chelomei was chosen mostly because he was already developing a heavy lift booster, the UR-500, that could be used for this mission (which later became the Proton and is still in use today).

The L1 and L3 programs were completely separate and competed for available funding. None of the research or techniques that were developed for one could be used by the other, so there was vast waste of resources due to duplicated efforts. This was unlike the American program where, for example, Apollo 8 (which was similar to the L2 mission) developed flight procedures for translunar flight that were used by all subsequent Apollo missions. The L1 and L3 programs shared only one piece of hardware: the top-most stage used on both the N-1 and UR-500 boosters, called the Blok-D. They both also used variations of the new Soyuz spacecraft, but in vastly different configurations—there was little choice, since it was the only crewed spacecraft the Soviet Union had under development at that time.

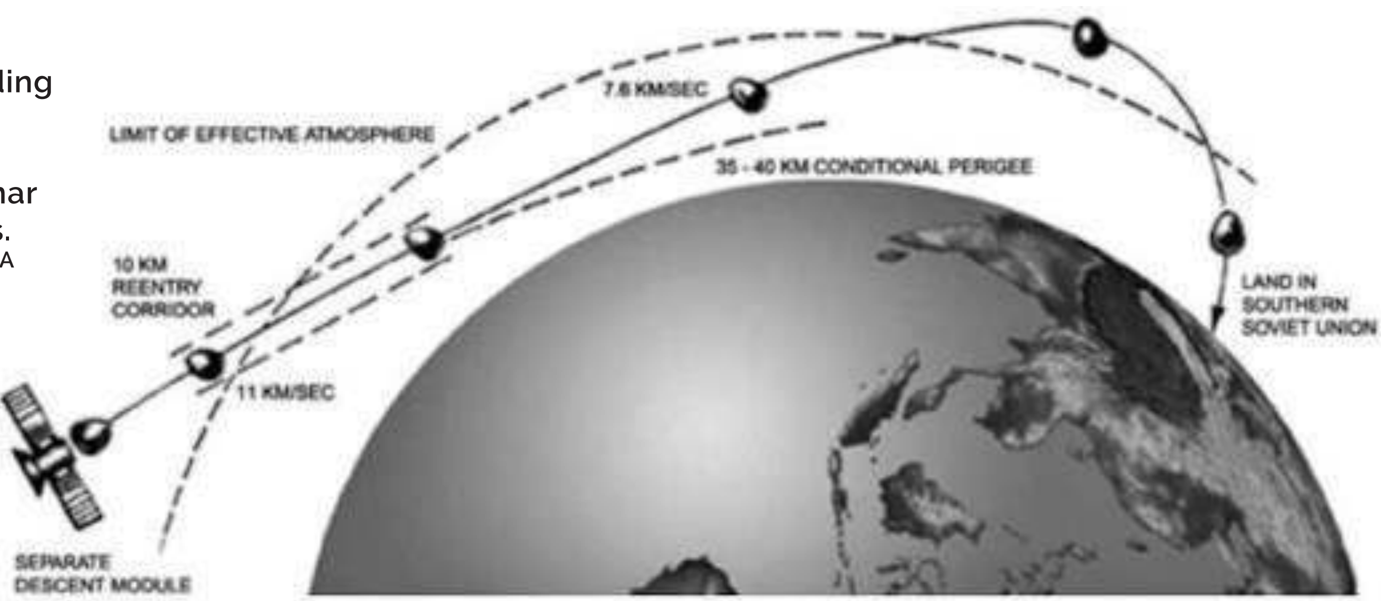
The Soyuz design was amazingly flexible, with various modules that could be customized and flown in different configurations. For Earth orbit and lunar missions, it was called 7K since it was the seventh design iteration and was made up of separate modules. For Korolev’s L3 program, it was designated Soyuz 7K-L3. Much like the Apollo Command and Service Module, this consisted of a multi-part crew section at the front and a service module at the back, powered by fuel cells and containing a large rocket engine for lunar orbit maneuvering and for boosting them back home. Unlike Apollo, the crew section consisted of two modules: the gumdrop-shaped reentry module in which the crew rode during launch and reentry, and a utility module that more than doubled the working volume for lunar transit, but was jettisoned before leaving lunar orbit to save weight.

Chelomei’s spacecraft needed to be lighter because of the lower lift capacity of the UR-500 booster compared to the N-1. There was no spherical utility module at the front, so the two cosmonauts would have to spend the week-long mission in an interior space the size of a Gemini capsule. The service module was shorter, as there was no rocket engine needed—this was intended as a flyby mission, not an orbital one. The program would ultimately be called Zond, the same name used for the Soviet robotic exploration program.

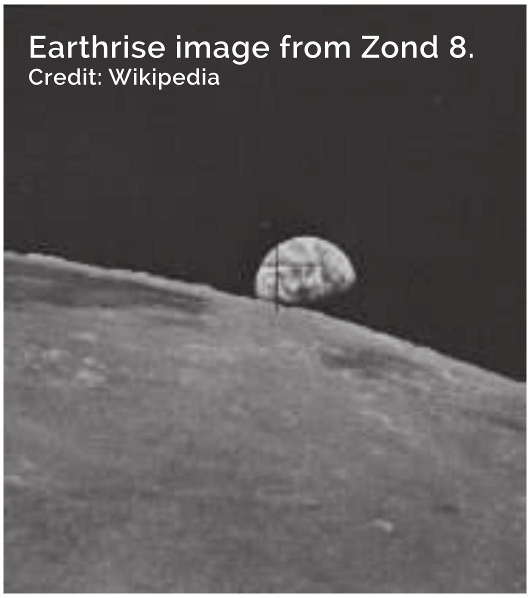
As both programs progressed, the Zond L1 lunar flyby program consumed resources that could have gone towards the L3 landing mission; yet the L1 was ultimately the only successful Soviet lunar effort, albeit without a crew. Following typical Soviet practice, the system used flight-test vehicles with far less testing and ground support than the crewed American programs did. Once the vehicle and booster were ready, the Soviets used the first flights to test the life support systems. But in place of cosmonauts, mission planners sent turtles, fruit flies, mealworms, seeds, and bacteria samples around the Moon along with scientific instruments and high-resolution film cameras.

There were eight Zond missions altogether—three interplanetary and five lunar. Zond 1 was sent to Venus, Zond 2 to Mars, and Zond 3 past the Moon and onward toward Mars orbit. Zond 4 through Zond 8 were the L1 lunar missions, all of which successfully looped around the Moon (or a Moon-equivalent distance) and returned to Earth.

The lunar missions were Zond 4 to 8. Zond 4 launched in March 1968, and was the first L1 mission. It flew into a looping orbit with a 220,000 mile (354,000 kilometer) apogee, but to avoid the complications from the Moon’s gravity should something go wrong, it was some distance away from the Moon. A guidance system failure prevented it from following the desired skip-trajectory on reentry (designed to lessen g-forces), so it was destroyed by controllers to prevent it from landing in non-Soviet territory. Without the skip trajectory, the g-forces and heat were probably beyond the endurance of a human crew, had one been onboard.



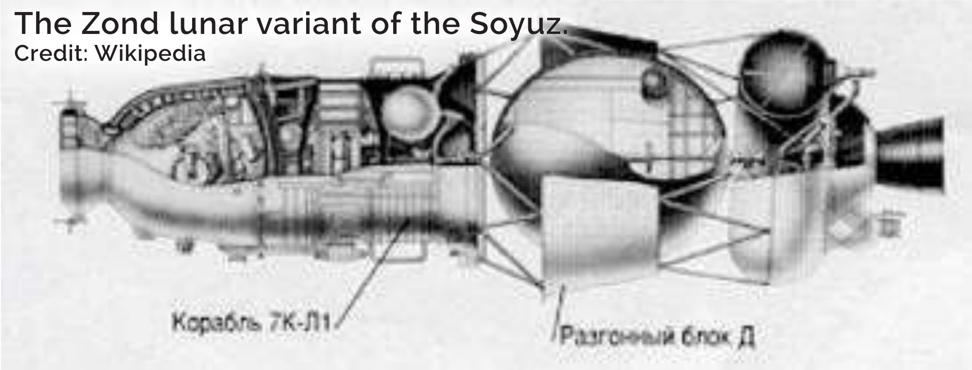
Reentry and landing diagram for the Zond lunar missions.
Credit: NASA



Earthrise image from Zond 8.
Credit: Wikipedia

Rollout of Zond 4 on its Proton booster.
Credit: Wikipedia

Soviet scientists inspect one of the tortoises from the flight of Zond 5.
Credit: Wikipedia



The Zond lunar variant of the Soyuz.
Credit: Wikipedia

Zond 5 launched in September 1968, and this mission was sent to the Moon, which it looped at a closest approach of 1,200 miles (1,931 kilometers). A guidance system failure again prevented the skip-reentry, but the trajectory allowed for that contingency and it landed in the Indian Ocean where it was recovered by the Soviet Navy. Even with the high g-forces of direct entry, the turtles and insects survived. Flying three months before Apollo 8, these creatures were the first living things to travel to the Moon and back.

Zond 6 flew in November 1968. This mission was a repeat of Zond 5, but this time the guidance system worked perfectly for the skip-trajectory. Unfortunately, a leaking hatch seal during the last stages of the mission de-pressurized the cabin, killing the biological specimens–however, humans would have survived if they had been wearing pressure suits.

Zond 7 launched in August 1969. This was the first Zond-L1 mission after the Apollo 11 landing. The Soviet leadership had considered sending cosmonauts, but with the Moon race lost, it would have appeared to be second-best. The mission was a complete success, with the reentry module landing only a few miles from the launch site as planned.

Zond 8, the last Zond mission, launched on October 1970. This final flight of the program took a large number of high resolution photos of the Moon and Earth, including their own version of Apollo 8's Earthrise image as the spacecraft rounded the lunar backside. This time the Soyuz performed its skip-reentry over the northern hemisphere to allow Soviet tracking stations to monitor reentry directly, leading to a landing in the Indian Ocean as intended.

At this point, the Zond-L1 system was considered operational and could be flown with a human crew. By then, however, the Americans had sent five crews to the Moon, with two of them (Apollo 8 and 10) being L2-style lunar orbiting missions, two others (Apollo 11 and 12) being L3-style landing missions, and one (Apollo 13) defaulting to an L1-type mission to get it home after an oxygen tank exploded on the spacecraft. If the Soviets had sent a manned Zond mission around the Moon after 1970, rather than showing the superiority of their system of government, it would have revealed the flaws of their space program. The government instead claimed that they had never been in a race with the Americans to land a human on the Moon.

In the end, the Zond flights proved the Soviet lunar hardware as flightworthy for a flyby mission to the Moon. Testing the U.S.S.R.'s lunar lander and associated modifications to the Soyuz for the L3 mission profile was another matter. In the end, the repeated failures of the N1 booster, the Soviet equivalent to the Saturn V, sealed the fate of their lunar landing program. But the first flights of living creatures past the Moon remains an intriguing footnote in the history of spaceflight.

The Apollo Guidance Computer
IN JIMMIE LOOCKE'S GARAGE

Martin J. Lollar, P.E.

What would you do with a surplus Apollo Guidance Computer, a true gem of the space age? Here is one man's quest to revive one such piece of space race history… with a lot of help from like-minded friends.

During December 2018 in a moderately sized hotel room in Humble, Texas, an Apollo Guidance Computer did what it was designed to do and executed approximately 2,000 instructions without errors. This 50-year-old piece of highly sophisticated and revolutionary 1960s vintage technology functioned perfectly using mostly original parts.

The small group in attendance marveled at the readings on a data scope, and stared in wonder at the result of months of research, detailed hand-tracing of old circuitry, and boundless hard work. The computer was alive and well.

So how did a critical piece of Apollo hardware, without which we never would have landed men on the Moon, end up in a hotel room surrounded by an expert technical team striving to resurrect it? The answer isn't simple but it is quite a tale, focused on one person: a sixth-generation Texan named Jimmie Wayne Loocke.

For those who might not be familiar with the Apollo Guidance Computer (AGC) and exactly where it fit in the scheme of NASA's Moon landing effort, a short history is in order. In any form of travel, the most important point in getting from one place to another is navigation. Today we take this for granted, using GPS satellites to give us our position to within a few inches. But the Apollo program began in the early 1960s, and the place we were headed to was 240,000 miles (386,243 kilometers) away in deep space. The astronauts had to know exactly where they were at any given time during the voyage and also be able to select a target and fly precisely to it in three-dimensional space. For this to occur, a robust and foolproof computer would be needed—one small enough to fit inside a cramped spacecraft.

Nothing like this existed at the time that would fit within the size requirements of the then-being-designed Command and Lunar Modules. NASA turned to the Massachusetts Institute Technology (MIT) to engineer the software for a revolutionary guidance computer. This first 'microcomputer' would have to be capable of working from manually-input star sightings, interfacing with a gyroscopic inertial platform, and taking complete control of all aspects of firing attitude control thrusters and the spacecraft's main engines; all with minimal human input. The effort was led by Eldon Hall, who worked at MIT's Instrumentation Laboratory. Hall convinced NASA that a new technology would be needed for this computer: the integrated circuit.

The final result, introduced in August 1966, was a 70-pound, 24-inch by 12-inch by 6.5-inch computer, with a then-unprecedented 2.048 MHz processor, 2,048 15-bit words of RAM, and 36,864 words of ROM. For the human interface, a keyboard and numeric display unit, called the Display and Keyboard Device (DSKY), was developed for entering values and observing outputs. One computer would be programmed for the Command Module, and another would be programmed for the Lunar Module.

The Lunar Module's primary contractor, Grumman Aircraft, was to deliver to NASA a number of Lunar Test Articles, or LTAs, which were various versions of the Lunar Module or facsimiles thereof that would be used to prove its operational abilities and flight-worthiness. One of the main tests was performed with LTA-8, which was held in late spring of 1968. This was a full man-rating test of the Lunar Module system conducted at the Johnson Spacecraft Center in a vacuum chamber that approximated as closely as possible the conditions that would be encountered in space. LTA-8 was subjected to a simulated altitude of 150 miles (241 km) and temperature of minus 300 degrees Fahrenheit. The test was crewed by NASA astronaut Jim Irwin and Grumman pilot Gerald Gibbons.

Apollo astronaut James Irwin and Grumman pilot Gerald Gibbons prepare for a test of Apollo hardware at the Johnson Space Center's vacuum chamber.
Credit: NASA

Grumman chose a group of engineers to send to the Johnson Space Center in Houston to support the LTA-8 test, and Loocke was among them. The Grumman team quickly got to work setting up the thermal equipment and preparing the chamber and the Lunar Module for the test, during which the team might work as many as 100 hours per week to stay on schedule. The first lunar landing attempt loomed large on the schedule, just months away.

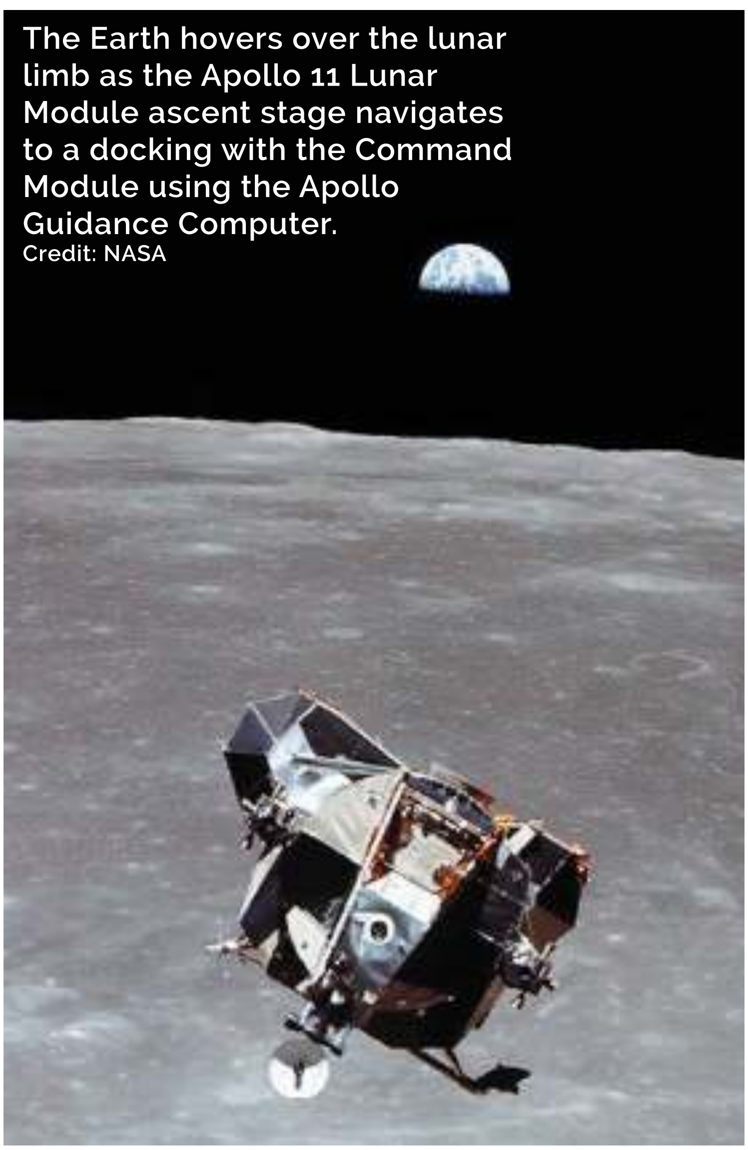
The test was successful enough to man-rate the Lunar Module and prove its integration and space-worthiness. NASA moved on to a Moon landing in 1969, Loocke moved back to Pasadena, Texas, and the LTA-8's Apollo Guidance Computer (AGC) moved to NASA's hardware graveyard, along with other

Apollo test articles that were no longer deemed critical to success.

Jump forward to the United States' Bicentennial in 1976, and Loocke was working on a project in his shop and needed some parts. He heard about Virgil Redgate, a metallurgist just across town who had a huge warehouse full of all kinds of electronics he had purchased at auction. The warehouse turned out to be so full, Loocke says, that he never did see more than about half of everything in it.

While searching there, Loocke spotted a lot of surplus NASA equipment, including parts of various spacecraft and items from the LTA-8 test. Loocke made an offer to Redgate for all the space-related items he could find. In short order, over two tons of former NASA hardware was moved to various places, including Loocke's garage. Loocke identified everything that he could, which included spare parts from the Surveyor IV mission, three Lunar Module ascent engines, and one item that he thought was an Apollo Guidance Computer. "I always had the idea in the back of my mind I wanted to fire it up, but that was a bit scary considering its age," Loocke said.

Around 1998, Loocke was selling some of his collectibles on eBay and wanted to determine his Apollo Guidance Computer's provenance. He contacted some former Draper Lab staffers who referred him to Eldon Hall. When Loocke got Hall on the phone, he described the computer and the condition it was in, and Hall said, "I'm flabbergasted!" Loocke's computer was, in fact, the LTA-8 item.



The Earth hovers over the lunar limb as the Apollo 11 Lunar Module ascent stage navigates to a docking with the Command Module using the Apollo Guidance Computer.
Credit: NASA

Loocke was still selling pieces of his space collection on eBay in 2016. One potential purchaser was Nick Howes, a test analyst at BMT Defense Services in the United Kingdom. Howes is also a very knowledgeable collector of flown space memorabilia, particularly Apollo hardware. The two struck up a friendship and Howes helped to identify some of the Apollo artifacts, including confirmation of the Apollo Guidance Computer's status. Howes also happened to be one of the main schedulers for Spacefest, a space race-focused conference held annually in Tucson, Arizona, and arranged for Loocke to debut the computer there.

At the same time, software engineer and hardware expert Mike Stewart was looking for an Apollo Guidance Computer to trace out the actual wiring and input/output connectors. Stewart had been gathering all the documentation he could find on the computer as part of a larger effort to possibly build one himself. He got in touch with Loocke, who explained his intention to power the 50-year-old computer up—as Stewart puts it, "He even brought up the idea of powering it up on that first phone call, which I couldn't believe! I think I asked him if he was serious." Of course he was.

Loocke and Stewart met at Spacefest in 2018, and the Apollo Guidance Computer drew considerable attention from the attendees. Now all that was left was to finish the technical work required to apply power and see if the computer could execute code after being dormant for 50 years.

Stewart assembled a team in a hotel room in Humble, Texas, all volunteers who traveled there on their own dime to run the test. The entire process is available on YouTube, with the computer visibly executing Apollo-era commands.

Work continues on the LTA-8 computer, with the goal of having it fully functional for the 50th anniversary of the Apollo 11 lunar landing on July, 2019. Howes is currently raising funds to take the computer back home to MIT and to fire it up with many of the original development team present, and possibly some Apollo astronauts.

The restoration and return to working order of this Apollo Guidance Computer is a strong testament to the original design team that crafted a ground-breaking, flight-worthy computer. The AGC was easily a decade ahead of its time, and this example still functions after 50 years of sitting idle. The project is also an example of how one person's passionate desire to preserve and share a very important piece of space history for future generations can bring out the best in people and bring them together. Perhaps most importantly, this reboot of an ancient piece of flight hardware serves to commemorate the groundbreaking Apollo program.

Not So Hidden:

Dr. George Carruthers, right, and William Conway, a project manager at the Naval Research Institute, examine the gold-plated ultraviolet camera/spectrograph, the Moon-based observatory that Carruthers developed for use on the Apollo 16 mission.
Credit: NASA

TEN Unsung Heroes OF APOLLO

Emily Carney

"[Apollo 11] was a perfect example of teamwork. Thousands of people [were] working on an unprecedented project like that, and nothing serious went wrong."

- Neil Armstrong, on a 1983 "Bob Hope's Salute to NASA" television special

Of the nearly half-million Americans who worked on the Apollo project, we hear mostly about the astronauts and key figures in Mission Control. But behind these noteworthy people were countless more from varied walks of life that are far less heralded. Here are profiles of ten of these exceptional people.

This past December, the spaceflight community celebrated the 50th anniversary of NASA's iconic Apollo 8 mission, in which humans orbited the Moon for the first time. During 2019, more Apollo anniversaries will continue, leading to July's remembrance of Apollo 11.

During these months, famous names will be discussed in countless documentaries, books, and articles commemorating these milestones; astronauts Frank Borman, James Lovell, William Anders, Neil Armstrong, Buzz Aldrin, and Michael Collins are just a few. But there are many other men and women who contributed to the successes of Apollo, who never made the journey but were integral to its success.

According to NASA, a workforce of over 400,000 made the Apollo lunar missions possible, from its nascent test phases in the early 1960s to its conclusion in 1972. NASA's Langley Research Center has stated that the program "required the support of over 20,000 industrial firms and universities." While it is impossible to profile each of the diverse personalities behind Apollo, here are ten unsung heroes of the program. Though they may have not launched atop a Saturn V, stepped on the Moon, or driven an electric car across the lunar terrain, each pioneered spaceflight in his or her own way. While this list is presented in alphabetical order, each figure—well-known or not—was essential to Apollo's success.

GEORGE CARRUTHERS

Born in 1939, Dr. George Carruthers was inspired by science fiction and the famous 1952 Dr. Wernher von Braun article "Man Will Conquer Space Soon," which appeared in "Collier's" magazine. "[Von Braun] was certainly a role model to me," Carruthers stated in the book "We Could Not Fail," written by Richard Paul and Steven Moss. "I wrote him a letter asking him for some information and he sent me an autographed letter as part of his response." A budding astronomer, Carruthers went on to earn several degrees from the University of Illinois, culminating in a doctorate in aeronautical and astronomical engineering. Shortly afterward, Carruthers was hired as a research physicist at the Naval Research Laboratory in Washington, D.C.

An inventor as well as an astronomer and engineer, Carruthers had secured a patent for a device called the Far Ultraviolet Electrographic Camera. In 1969, he submitted a proposal to NASA; his idea was to place one of his ultraviolet cameras on the lunar surface during an Apollo mission. While another scientist, Thornton Page, had submitted a similar proposal, this did not mark the end of Carruthers' ambitions. He and Page worked together on the Far Ultraviolet Camera/Spectrograph telescope.

In April 1972, the duo's invention was placed on the Moon during the Apollo 16 mission. Carruthers emphasized its importance in a NASA oral history interview: "The most immediately obvious and spectacular results were really for the Earth observations, because this was the first time that Earth had been photographed from a distance in ultraviolet light, so that you could see the full extent of the hydrogen atmosphere, the polar auroras, and what we call the tropical airglow belt." Carruthers' camera remains in the Descartes Highlands region to this day, flanked by the descent stage of the Lunar Module *Orion*, a permanent monument to the ingenuity of the Apollo Program.

Wernher von Braun, to left, and Kurt Debus in front of a Saturn V mockup in 1966.
Credit: NASA

KURT H. DEBUS

Dr. Kurt Debus' journey to Apollo took him from postwar Germany to Fort Bliss, Texas, then to Huntsville, Alabama, before finally reaching Cape Canaveral, Florida during the early 1950s. According to a NASA biography, "Debus supervised the development and construction of rocket launch facilities at Cape Canaveral for the Redstone, Jupiter, Jupiter C, Juno, and Pershing military configurations beginning in 1952 and continuing through 1960. The organization he directed was transferred from the Army to NASA."

His major contribution to Apollo's history was to supervise the development and construction of the Apollo and Saturn launch sites at Cape Canaveral Air Force Station and the Kennedy Space Center, becoming the latter's first center director in 1962. In this role, he oversaw 13 successful launches of the Saturn V, beginning with 1967's Apollo 4 and ending with 1973's Skylab space station, as well as the construction of such iconic facilities as the massive Vehicle Assembly Building. In a NASA recording following Apollo 4's flight, Debus enthused about the assembly of a successful launch team. "I'm very proud of these people who have done all they possibly could, who have sacrificed much of their own personal life for an ideal, for a goal, which is to give this nation a powerful new rocket in its stable."

Debus was Kennedy Space Center's director until his retirement in 1974. A NASA interview with his daughter, Sigi Northcutt, underscored his reticence to be in the spotlight: "He did not take credit himself; he felt [the space program] was everybody's baby," she said. Debus' contributions to spaceflight history are still remembered; in last year's movie "First Man," he was played by James Hansen, the author of the Neil Armstrong biography on which the film was based.

Margaret Hamilton with printouts of the Apollo Guidance Computer's software.
Credit: NASA/MIT

Left: Tom Kelly, known as the "father of the Lunar Module," at foreground left.
Credit: NASA

Above: William Moon
Credit: NASA

MARGARET HAMILTON

Some women break the glass ceiling, and some rocket right through it—Margaret Hamilton was definitely in the latter category. In 1961, NASA awarded the first contract for the Apollo program to the Massachusetts Institute of Technology (MIT) for a flyable computerized guidance and navigation system. Hamilton, a computer scientist who was the director of Software Engineering at the MIT Instrumentation Laboratory (now the Charles Stark Draper Laboratory), led the team that developed the software for Apollo.

They saw their software tested to the limit during the landing of Apollo 11, when the Lunar Module *Eagle's* computer encountered a "1202" alarm. This meant that the computer had become overloaded with tasks, and indicated that the system's software was dismissing less important chores to focus on more important ones. Despite this alarm, Flight Director Gene Kranz allowed the landing to proceed.

As Hamilton wrote in "Datamation" magazine, "The computer (or rather the software in it) was smart enough to recognize that it was being asked to perform more tasks than it should be performing." If MIT's team had not written software that prioritized tasks, it is doubtful Armstrong and Aldrin would have landed on the Moon July 20, 1969. In 2016, Hamilton was awarded the nation's highest civilian honor, the Presidential Medal of Freedom, by President Barack Obama. Her contributions to her field undoubtedly made the first lunar landing a reality.

SHELBY JACOBS

Reaching adulthood at the dawn of the civil rights era, Shelby Jacobs was well aware of the obstacles that he faced in his quest to become a mechanical engineer as an African-American. He was encouraged to pursue trade work because, in his high school principal's words, there were "no black engineers." His principal further warned him about the prejudice he would encounter while attending the University of California, Los Angeles (UCLA), to which he had been awarded a full scholarship. Jacobs stated, "I didn't take his comments negatively. He was letting me know the playing field was not level and I appreciated his honesty." A student with a natural aptitude for math and science, he excelled regardless of his principal's warnings.

After graduating from UCLA, Jacobs was one of only eight African-Americans hired at Rocketdyne, which then employed 5,000 engineers. Transferred to North American Aviation soon after, Jacobs was responsible for the design, installation, and testing of the camera system that recorded the rocket staging during the Apollo 6 mission. The iconic film of an aft interstage skirt separating from the rocket would not have been possible if it had not been for Jacobs' ingenuity. This film sequence is still used in Apollo documentaries to show the Saturn V's unique staging characteristics.

However, Jacobs' career did not end with Apollo. During the space shuttle program, he worked as a project manager for the external tank's disconnect systems. Recently, Jacobs' historic career and life have been celebrated in an exhibit featured at Downey, California's Columbia Memorial Space Center, called "The Life and Dreams of Shelby Jacobs."

TOM KELLY

Described as the "father of the Lunar Module," Tom Kelly was Grumman Aircraft's chief engineer assigned to the Lunar Module, which would prove its mettle as the world's first true spaceship–it was the only crewed vehicle to ever fly only in a vacuum. Kelly and his team were not only responsible for the myriad design changes the module underwent from its inception in 1962 to its nine crewed flights, but they also helped to refine the lunar orbit rendezvous methods critical to the Apollo program.

While many have said that the Lunar Module was not an aesthetically beautiful vehicle, Kelly emphasized its functionality. "You have to remember that the Lunar Module was carried in the Saturn's protective shroud and only operated in the vacuum of space. That allowed us to design it from the inside out because we had no concerns for aerodynamics at all, which resulted in the distinctive look for the module," he related in a September, 2001 "Air & Space" magazine article. The Lunar Module also famously kept the Apollo 13 crew of Jim Lovell, Fred Haise, and Jack Swigert alive in April, 1970 after their Command and Service Module suffered a near-catastrophic oxygen tank explosion in space.

Kelly spent over five years writing his memoirs of his time designing the Lunar Module, called "Moon Lander: How We Developed the Apollo Lunar Module." According to a New York Times obituary, he once said, "Nobody at Grumman who worked on the Lunar Module will ever forget it. We all knew that we were part of a majestic endeavor, and that we were making history happen."

William Moon

Born in rural Mississippi to Chinese immigrant parents, William Moon never imagined that he would one day be a member of one of the most exclusive engineering fraternities of all time: Johnson Space Center's Mission Control. After graduating from Mississippi State University, he was hired by NASA in 1964 as an Apollo Electrical, Environmental, and Consumables Manager (EECOM). Training under one of the most famous managers, Sy Libergot, Moon worked on the EECOM control console during the last three Apollo missions, Apollo 15, 16, and 17. He was also the first Asian-American to work in Mission Control.

Moon recalls the wonder of the Apollo era to this day. "What made Apollo so special and so distinctive was the goal set by President Kennedy to land a man on the Moon in that decade. To me, working on Apollo as a Flight Controller was a very unique job in that very few people were flying and controlling space vehicles, no less flying men to the Moon," he said. "What made it so magical and special was here we were, a group of young college graduates in our mid-twenties from small towns and colleges, working as team to put and keep America in front in the big space race with the Soviet Union. I guess we can attribute that to the great leaders we had leading us in this endeavor, such as [Gene] Kranz, [Chris] Kraft, and [Robert] Gilruth."

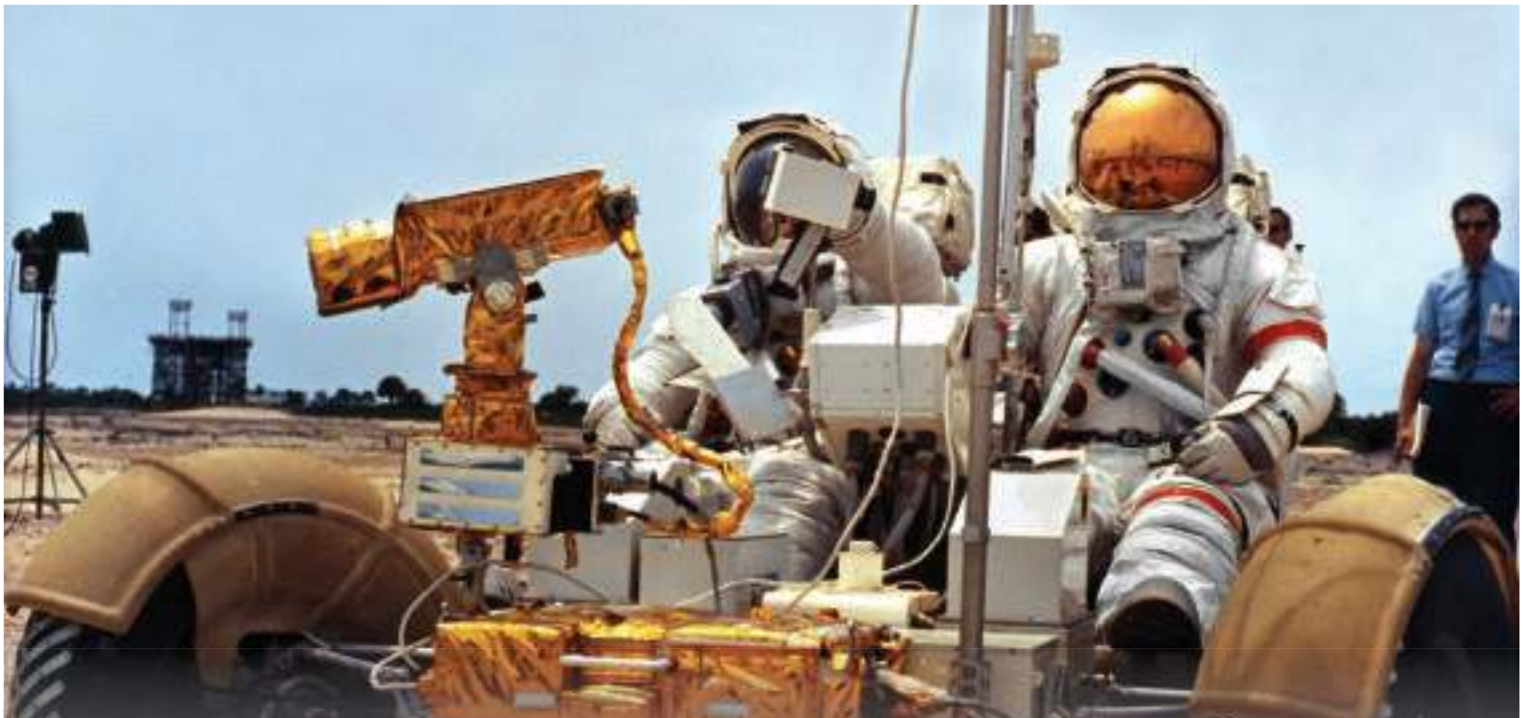
Moon's time in the Mission Operations Control Room did not end with Apollo 17. He continued to work the consoles during the Skylab program, the Apollo-Soyuz Test Project, and the space shuttle. Retired from NASA since 2002, Moon is a central figure in a number of Apollo documentaries and books.

Saverio "Sonny" Morea

Each space mission is at the mercy of its launch vehicle, and nobody was more aware of this than Saverio "Sonny" Morea, who left an indelible mark on the mammoth Saturn V rocket, which had to work flawlessly to make lunar missions possible. In 1960, Morea transferred to NASA's Marshall Space Flight Center to work with Wernher von Braun's team, and became the F-1 engine project manager. The Saturn V's first stage possessed five F-1 engines, with over 7.5 million pounds (3.4 million kilograms) of combined thrust. However, early tests showed a problem with combustion instability, which resulted in the powerplant's destruction during more than one test. His team was under pressure to come up with a quick solution. Morea said in the recent PBS NOVA special "Apollo's Daring Mission," "The solution had to come by trial and error."

Morea's team solved the instability problem by adding baffles to the engines' injector plates, which served to better disperse the liqud fuel for even combustion. In addition to working on the F-1 engine, Morea also strove to make the J-2 engine more reliable. The J-2 engines were located on the Saturn V's second stage in a cluster of five, with one more on its final stage. Thanks to Morea and his team, the Saturn V rocket was a workhorse that delivered all of its crews successfully to space.

Morea wasn't finished with Apollo, however. By 1969, NASA was looking to send a "Moon car" on Apollo missions to aid in lunar exploration. He led the team that developed the Lunar Roving Vehicle, which included another unsung hero profiled in this piece, Ferenc Pavlics. Morea's team would deliver a roving vehicle to the lunar surface within 18 months of the project's inception.



James Irwin, to left, and mission commander David Scott, testing Apollo 15's Lunar Roving Vehicle.
Credit: NASA

Frances "Poppy" Northcutt
Credit: NASA

Wernher von Braun, to left, laughs with George Mueller in the Apollo Firing Room.
Credit: NASA

GEORGE E. MUELLER

As the leader of NASA's Office of Manned Spaceflight (now the Human Operations and Exploration Mission Directorate) from 1963 to 1969, George Mueller's concept of "all-up" testing ensured that human bootprints were made on the Moon before President Kennedy's end-of-the-decade deadline. NASA history volume "Apollo Expeditions to the Moon" explains Mueller's daring philosophy: "Instead of beginning with a ballasted first-stage flight as in the Saturn I program, adding a live second stage only after the first stage had proven its flightworthiness, his 'all-up' concept was startling. It meant nothing less than that the very first flight would be conducted with all three live stages of the giant Saturn V … It sounded reckless, but George Mueller's reasoning was impeccable."

Mueller's risk-taking paid off, and two uncrewed Saturn V's were launched: one on November, 1967 and another on April, 1968. While the latter Apollo 6 launch experienced difficulties, Mueller and his team were confident enough in the vehicle that the next launch, Apollo 8, carried three men into lunar orbit.

Mueller's influence didn't just change the course of Apollo. According to NASA, he was responsible for expediting the earlier Gemini program and championed reusable space vehicles, paving the way for the space shuttle. His simple pen-and-ink sketch of a space station would also eventually be realized as Skylab, America's first outpost in space.

FRANCES "POPPY" NORTHCUTT

Frances M. "Poppy" Northcutt pushed past the limits that existed for women in engineering as one of the first women to work in the male-dominated Mission Control. A seasoned mathematician at the age of 22, she was hired to work as a "computress" at NASA contractor TRW. In a NASA oral history project, she detailed her involvement in Apollo 8 and the "successful failure" of Apollo 13. "We worked for Mission Planning and Analysis … That is who we were contracted for, and the particular contract I was on, we did the design and the development of the return to Earth program that was used in the real-time computer center," she remembered.

Northcutt was careful, though, to give her entire team credit: "I don't ever like to say that any one of us did it alone … That was absolutely a complete teamwork kind of thing. But our program was what was used to compute those maneuvers to come home and it was initially planned that we would not be over there in the [Mission Control] Center. We weren't supposed to have been there as originally planned, but we ended up over there as support because it was a pretty complex program."

Articles from that time described her as a former beauty pageant contestant, and a tall, "fun-loving" blonde. Her achievements paved the way for scores of future women in Mission Control, including the National Space Society's own Marianne J. Dyson, who was a Flight Activities Officer during the shuttle program. After her work in the space program, Northcutt became quite active in the National Organization for Women, and became the first Women's Advocate of the city of Houston, Texas.

FERENC PAVLICS

Born in Hungary in 1928, Ferenc Pavlics was educated as a mechanical engineer in his homeland. Following the 1956 revolution in Hungary, he and his wife settled in Austria, then emigrated to the United States, where he soon found work at General Motors in Detroit, and then in Santa Barbara. In a "Quest" magazine interview, Pavlics underscored how his education in Eastern Europe gave him a desirable skill set, and how he was hired while he was still in Camp Kilmer, a military base used to house immigrants. "The U.S. National Academy of Sciences was calling on industry to try and give jobs to refugees, and so Dr. [Mieczyslaw] Bekker came to the camp. Less than a week after my wife and I arrived, Bekker interviewed five Hungarian engineers and hired all of us."

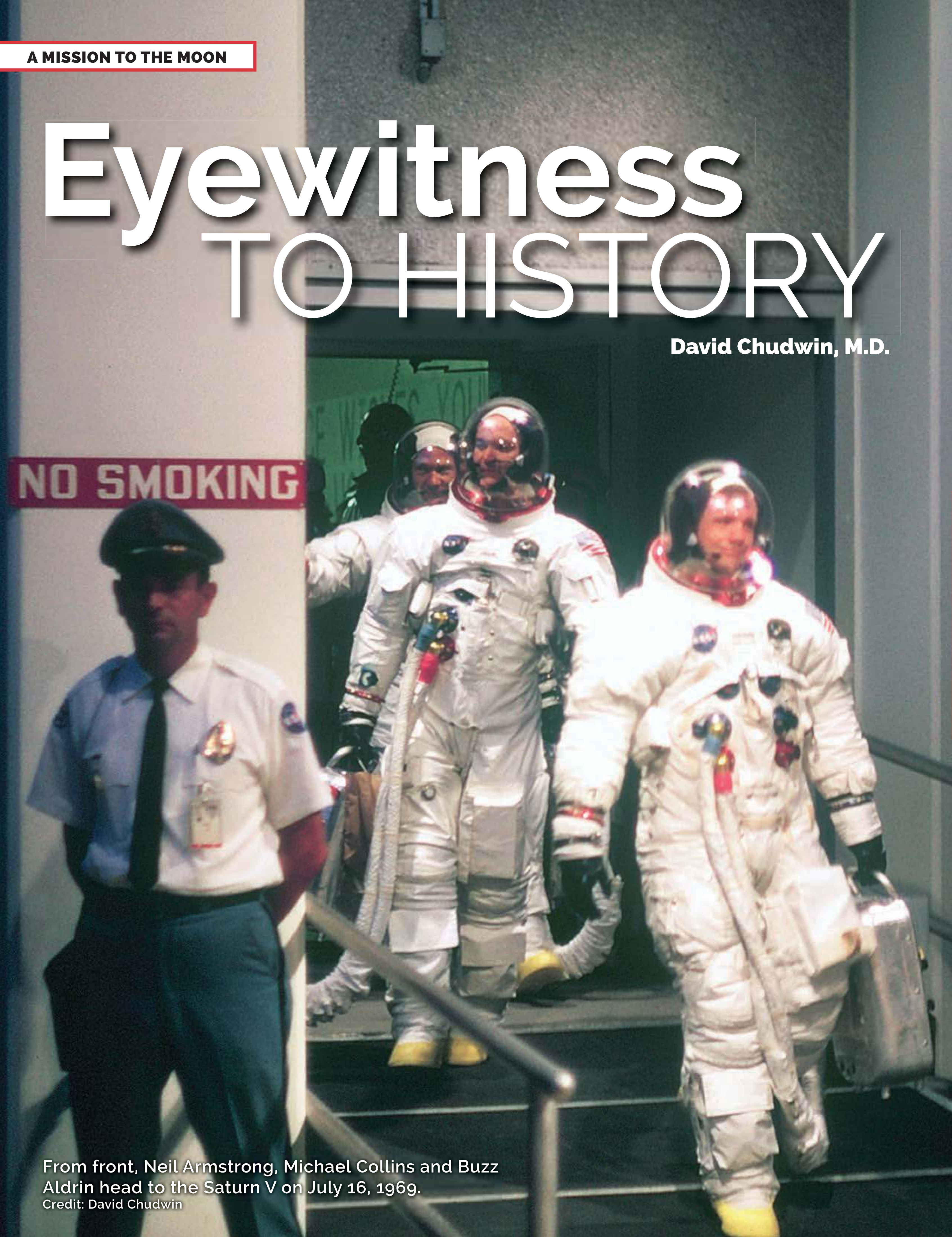
Pavlics' vision soon turned to space, as the idea of rovers driving on other worlds was discussed in the early 1960s. While Boeing is credited as the primary contractor for the Lunar Roving Vehicle, General Motors was responsible for the vehicle's drive train and controls. Pavlics said, "Boeing would handle the power system, navigation, communication, and integration with the [Lunar Module], and General Motors would do the vehicle itself, including the chassis, wheels, suspension, steering, electric drive, controls, and displays." The General Motors team, working under contract to Boeing and fronted by Pavlics, had only 18 months to develop and build the first vehicle, which was used during 1971's Apollo 15 mission.

Pavlics was also careful to emphasize that the Lunar Roving Vehicle's success was due to teamwork. "This was a highly compressed schedule. Nothing in Apollo had been started and stopped like this. It was day and night, weekends; our families hardly saw us. Nobody died, but some people got sick. But the great thing was the people were so enthusiastic. You didn't have to prompt people, or ask, 'Can you stay an extra hour today?' Everyone volunteered and worked together; 400 people from Santa Barbara working on this in a very enthusiastic team effort."

Pavlics' comments, and those of the nine other unsung heroes, capture the essence of the Apollo spirit: hundreds of thousands of diverse leaders, engineers, scientists, and workers banding together to focus on one common goal, the exploration of the Moon by human beings.

Eyewitness TO HISTORY

David Chudwin, M.D.



From front, Neil Armstrong, Michael Collins and Buzz Aldrin head to the Saturn V on July 16, 1969.
Credit: David Chudwin

Left to right,
Astronauts Alan Bean, Jim Irwin, Charles Duke, and Bruce McCandless at the Melbourne, Florida airport on July 13, 1969.
Credit: David Chudwin

The mission of Apollo 11 was covered primarily by seasoned, mid-life journalists. But one teenager managed to wrangle a press pass—here is David Chudwin's account of the events of July, 1969, complete with exclusive photos he took of the events.

The touchdown of the Lunar Module Eagle on the Moon on July 20, 1969 was the culmination of over eight years of hard work. The Apollo 11 flight fulfilled President Kennedy's goal to land humans on the Moon by 1970.

Engineers, scientists, tradesmen, administrators, and ordinary citizens worked overtime, at night, and on weekends to fulfill Kennedy's ambitious plan.

When it came time to attempt the first crewed lunar landing, the space agency invited a wide range of special guests and hundreds of journalists to view the liftoff of Neil Armstrong, Michael Collins, and Buzz Aldrin aboard a Saturn V rocket. NASA had invited numerous politicians, military brass, industrialists, former NASA officials, writers, and entertainers to watch the launch from the Kennedy Space Center ("KSC") in Florida. I was lucky to be there in person on July 16, 1969 and rub shoulders with these notables.

I was present for the launch and pre-launch activities at KSC as a young, wide-eyed college journalist among about 3,500 other media representatives. Along with a friend, I was the only reporter from the college press with NASA press credentials. Writing for "The Michigan Daily" and the College Press Service, I covered the Apollo 11 launch from KSC and the Apollo 11 News Center, located for that mission in nearby Cape Canaveral. I had just turned 19 on July 11 and was one of the only teenagers there with a NASA press pass.

The days before the launch were an exciting experience for me. I flew down from Chicago on July 13 on the same plane as Rose Cernan, the mother of astronaut Gene Cernan. I recognized her from attending events in Bellwood, Illinois welcoming home her son after his Gemini 9 and Apollo 10 flights. Cernan was occupied that day, so his fellow astronaut Alan Bean was at the Melbourne, Florida, airport to greet her. He was accompanied by astronauts James Irwin, Charlie Duke, and Bruce McCandless. Mrs. Cernan introduced us to Bean and the others, who were there to pick up family

The Saturn V carrying Armstrong, Collins, and Aldrin lifts off from Pad 39A on July 16, 1969.
Credit: David Chudwin

President Lyndon Johnson, lower center, attends the launch of Apollo 11, a program that developed primarily when he was in office.
Credit: David Chudwin

members coming to see the launch.

We chatted with the astronauts for a few minutes before going outside to pick up our luggage; it was late, so we waited with them outside the small terminal. At my request, Jim Irwin snapped a picture of Alan Bean and I. Bean was the only one with a flight assignment at the time, so he was the best known of the group. It seemed a good omen for the trip that I stepped off the plane and met four NASA astronauts, three who later walked on the Moon, and McCandless, who made the first free-flying space walk in Earth orbit during the shuttle program.

The astronauts were the first but not the last of the space rock stars I encountered covering the Apollo 11 launch. There were two major press conferences for reporters with NASA officials that I attended. These gatherings were a chance for me to see some of the pioneers of space exploration in person. One event was the "Center Directors Briefing" on July 14, which featured George Mueller, the Associate Administrator for Manned Space Flight; Wernher von Braun, the Marshall Space Flight Center director; Robert Gilruth, the Director of the Manned Spacecraft Center; Kurt Debus, the Director of the Kennedy Space Center; and John Clark of the Goddard Space Flight Center.

These men were responsible for important components of the Apollo program, such as the Saturn V rocket, the Apollo spacecraft, the launch facilities, and the tracking facilities. As a NASA Associate Administrator, Mueller was ultimately in charge of the Apollo program. For a teenager to be in the same room at the Apollo 11 News Center with these space giants and hear them speak was incredibly exciting. During the press conference, von Braun compared the first Moon landing to aquatic life leaving the oceans for dry land. That statement seemed a bit over-the-top at the time, but it led me to contemplate the important role of the Apollo program in human history, a key concept in the epilogue of my new book "I Was a Teenage Space Reporter: From Apollo 11 to Our Future in Space."

A later press conference, held at the Launch Complex 39 press site on July 15, the day before launch, featured the top operational personnel for the Apollo 11 mission. Apollo spacecraft program manager George Low, mission director George Hage, chief astronaut Deke Slayton, launch director Rocco Petrone, and astronaut physician Charles Berry, among others, discussed preparations for the launch. I watched the briefing with other reporters from the press grandstand with the officials situated on a stage in front of us.

During the various pre-launch activities, I encountered other memorable figures such as CBS News anchor Walter Cronkite, who was holding court poolside at the Cape Kennedy Hilton. I also saw

Jubilation in Misson Control upon the successful conclusion of the Apollo 11 mission.
Credit: David Chudwin

him in person again when he and three other journalists did a live remote television interview with the Apollo 11 crew. Cronkite and the panel at the Apollo 11 News Center asked questions by closed circuit television while the astronauts were in quarantine in their crew quarters.

NASA had invited hundreds of dignitaries—politicians, military brass, foreign ambassadors, leaders of commerce and industry, writers, and entertainers—to witness the launch. Early on the morning of Wednesday, July 16, the invited guests were bused to a the VIP viewing site. There were several low grandstands located about three and a half miles from the Saturn V. Originally, I was going to watch the liftoff from the press site, but decided to take a NASA press bus to the VIP site instead. This area gradually filled up with notables from all walks of American society, as well as foreign ambassadors and representatives. I watched as they arrived and took their seats in the grandstands.

The highest-ranking politician present was former President Lyndon B. Johnson and his wife Lady Bird. Accompanied by Secret Service agents and wearing a dark blue suit despite the humid weather, Johnson received a warm welcome and stood up from his seat to acknowledge the applause of the crowd. He had been the "godfather" of the space program after Kennedy's assassination in 1963. While a senator, Johnson was chairman of the Senate Space Committee, and as vice president he was head of the National Space Council.

Richard Nixon, who took office after Johnson, had decided to stay at the White House but sent Vice President Spiro Agnew to Florida. Agnew watched the liftoff from inside the Launch Control Center but later stopped by the VIP site.

Former NASA Administrator James Webb was seated near Johnson, who had helped arrange his appointment to head the space agency in 1961. Webb resigned his position in October, 1968, but was well-respected for leading NASA through the preparation for a lunar landing. I saw a number of current and former senators, including Barry Goldwater, Kenneth Keating, and William Proxmire. I thought it odd that Proxmire, who had attacked the space program and was always trying to cut NASA's budget, showed up for the launch.

Representing the Kennedy family, R. Sargent Shriver was also there. The founding director of the Peace Corps, Shriver was married to Eunice Kennedy, the late president's sister.

Looking around the grandstands, I was able to recognize some famous entertainers of the time. Television personalities Johnny Carson and Ed McMahon were signing autographs for fans. Pulitzer Prize-winning writer Norman Mailer was also there, and later wrote the 1971 book "Of a Fire on the Moon" about his experiences.

However, as the launch time started to approach, I turned my attention from people watching to the mammoth 363 feet (111 meters) tall Saturn V rocket three and a half miles (5.6 kilometers) away on Launch Pad 39A. This was the closest distance from which spectators could safely watch a Saturn V launch without risking injury in case the rocket blew up. My friend and I staked out some space on the grassy lawn in front of the VIP grandstands and waited as the countdown proceeded smoothly. The distinctive voice of NASA Public Affairs Officer Jack King could be heard over loudspeakers marking each milestone in the countdown. Everything was proceeding according to plan.

The sky was blue with a few scattered clouds. Temperatures were warm and humid—normal for a Florida morning—but not hot or oppressive. There was a feeling of anticipation in the air, as well as concern. It was not unusual for rocket launches to be delayed due to mechanical or electronic issues, weather, or other problems. Sometimes the problems were serious enough to lead to a postponement—a "scrub."

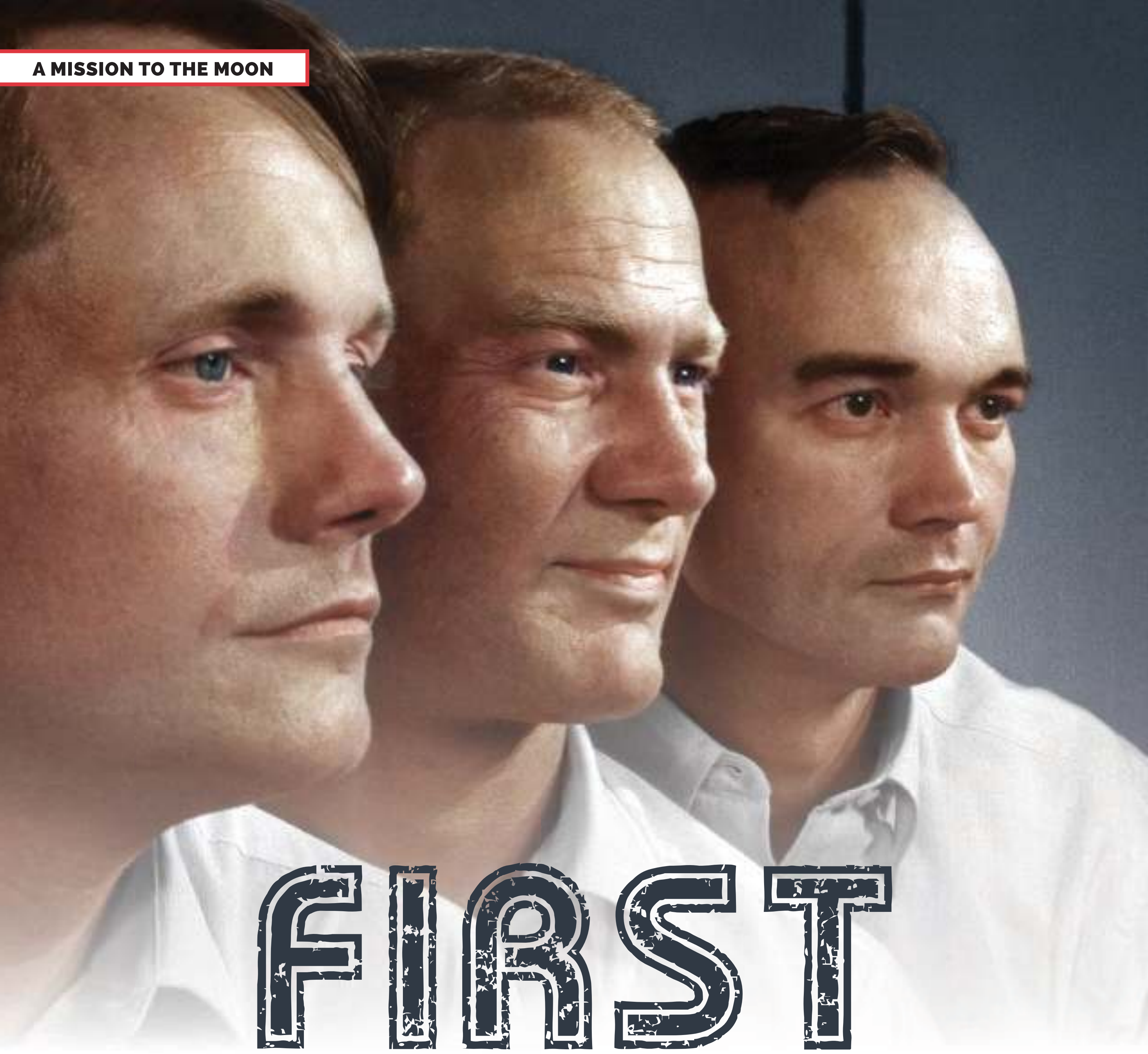
People were worried because Apollo 11 was only the fourth crewed flight of the Saturn V rocket. Armstrong, Collins, and Aldrin were sitting on an explosive mixture of 318,000 gallons (1,200,000 liters) of liquid oxygen and 203,400 gallons (770,000 liters) of kerosene fuel in the first stage alone. Although it had a perfect safety record up to that point, there were always concerns about an explosion. Even if the liftoff were to happen that day, a successful landing and return from the Moon was by no means assured. Rough estimates by the astronauts and NASA officials were that they had at best a fifty-fifty chance of success on the first try. NASA Administrator Thomas Paine told the crew in a private meeting not to take unnecessary risks; he made them an unprecedented promise that they would get a second shot with another flight if they had to abort the landing for safety reasons.

The Apollo 11 flight plan was complicated. It involved a two-stage lunar lander separating from the command ship in orbit around the Moon, flying down to the surface, and then using the upper stage of the lander to launch from the Moon to rendezvous and dock with the Command Module in lunar orbit. This scheme, called Lunar Orbit Rendezvous, was an audacious decision made before any of the hardware had been built and before rendezvous and docking had been accomplished in Earth orbit, let alone around the Moon. A lot could go wrong on the Moon or while in orbit, but the main concern on that Wednesday morning was a successful launch of Armstrong, Collins, and Aldrin. I started taking a sequence of pictures with seconds to go and actually watched the launch through the viewfinder of my camera.

Ignition occurred right on schedule at 9:32 a.m. Eastern Time and I saw a dot of orange-yellow flame at the base of the Saturn V rocket. Then smoke and flames shot out hundreds of feet from each side of the Saturn V, deflected by a system of trenches and concrete wedges. The rocket just sat there for what seemed like an eternity but was actually just a few seconds, and then started to rise very slowly off the launch pad. We could see this but it took several seconds for the sound to reach us—we were gradually engulfed by a crackling sound so loud that one felt as well as heard it. The sound waves physically pounded our bodies.

As the rocket cleared the tower, not only could I hear and feel the roar but also the heat generated by the Saturn V as it pounded skyward. At a surprisingly slow pace at first, the rocket gradually accelerated into the partly cloudy blue sky. Soon all that could be seen was a dot of bright light. The roar gradually faded and then all one could hear were the cheers from the crowd for the awesome sight they had seen. Neil Armstrong, Mike Collins, and Buzz Aldrin were on their way to the Moon, and we had been eyewitnesses to history that morning. It was an experience that would change my life and those of countless others–the opening of the lunar frontier.

David Chudwin, M.D. (seen here in 1969), is the author of the new book "I Was a Teenage Space Reporter: From Apollo 11 to Our Future in Space" (LID Publishing).



FIRST ON THE MOON

APOLLO 11'S DANGEROUS MISSION

Rod Pyle

Hundreds of things had to go according to plan for Apollo 11 to land astronauts on the Moon and return them to Earth successfully. The flight proceeded mostly generally as planned, but there were a number of potential mission-stoppers that the general public only learned about later.

The story of humanity's first visit to another world is one that is well known. But this grand saga, one filled with drama and grandeur, often omits many details–the small moments of apprehension, concern, and sometimes even fear–which attended the mission of Apollo 11, carrying the first crew to attempt a landing on the Moon.

COMPUTER ALARM!

Neil Armstrong, Buzz Aldrin, and Michael Collins departed Earth from the Kennedy Space Center on July 16, 1969. Three days later they were in lunar orbit. On July 20, Armstrong and Aldrin entered the Lunar Module (LM), and fired its descent engine to initiate their long fall to *Mare Tranquilitatis*, dozens of miles below them.

The Apollo 11 Lunar Module *Eagle* was passing 33,000 feet (about 10,000 meters), headed to the Moon below, when the first alarm went off. The *Eagle's* guidance computer had become overloaded and locked up, displaying a numeric error message on its display: "1202." After a flawless launch, a by-the-numbers transit across 240,000 miles (386,243 kilometers) of space to the Moon, and having braked the Command and Service Module (CSM) *Columbia* into lunar orbit, a computer malfunction could cause America's first landing on the Moon to be scrubbed over a few errant electrons.

Neil Armstrong, who was piloting the *Eagle*, looked at the readout with concern, as Buzz Aldrin, his comrade in this great adventure, continued to watch the computer, as he had been throughout. Neither man knew what the alarm meant—only that it represented a potential mission scrub and could cause them to cut short the landing attempt. Landing on the Moon was not something that could be eyeballed, like setting down at a local airstrip on Earth. If the computer failed, they would have to abort, staging the LM and making an emergency ascent back to Mike Collins and the waiting CSM in orbit, a potentially dangerous maneuver.

"Program Alarm," Armstrong said, with the slightest edge of tension in his voice. "It's a 1202." The radio signal between the LM and Mission Control had been weak, so Aldrin repeated, "1202."

In Houston, flight controllers scrambled to discern what the 1202 code meant, as nobody had recognized it immediately. Then a call came from a team of engineers in an operations support room adjacent to Mission Control, and Steve Bales, the controller responsible for the navigation computer, told Flight Director Gene Kranz that it was okay to proceed. Relieved but still concerned, Kranz assented.

What the 1202 computer alarm looked like to Armstrong and Aldrin aboard the Lunar Module. This is a modern reproduction of the Apollo Guidance Computer. Credit: Nick Howes

Armstrong continued the descent, taking manual control of the *Eagle* and concentrating on the cratered landscape that was passing below them. Aldrin kept his eyes on the computer display, giving a running account of the readout. The machine locked up a few more times, with both "1202" and "1201" errors, but these were determined to be non-critical, and the landing continued. These computer interrupts were designed to keep the guidance computer from shutting down in the event of a data overload—which it was now experiencing—and told the machine to disregard non-critical duties and concentrate on only the most necessary ones.

Most people listening on radios and televisions across the world didn't have any idea that there had been a serious risk of an abort due to a balky computer. Even fellow astronaut Wally

Schirra, who was sharing the commentating duties with news anchor Walter Cronkite at CBS News, fumbled a question from Cronkite; he had no real idea what it was either.

FUEL LEVEL: CRITICAL

By now Armstrong also realized that they were way off target—nothing he saw below matched the lunar maps that had been painstakingly generated over the years from robotic orbiters and the two Apollo missions that had preceded them to the Moon. They were "landing long" in pilot's parlance, and had overshot the planned landing zone. Analysts would later determine that a small amount of air in the docking tunnel between the CSM and LM had given the lander a bit of extra push upon undocking, which added to their velocity in orbit. The result of that gentle nudge was that as the duo neared the lunar surface, Armstrong was no longer searching for the planned landing site; he was searching for *any* safe landing site, and fuel was draining quickly.

"Sixty seconds," came the warning from Charlie Duke, a fellow astronaut and the CAPCOM (Capsule Communicator) back in Mission Control. The *Eagle* was still 75 feet (23 meters) above the surface, and their descent had now stopped. Armstrong was scooting horizontally above the Moon in a hover, searching for any place that was flat and un-cratered enough, and sufficiently free of boulders, to set his flying machine down.

He didn't see much that was not a LM-wrecker below. Any rock over a foot high could cause the machine to topple or be unable to launch them toward home, as could any crater of the same depth. Armstrong gripped the controller, concentrating intently, and Aldrin continued to read off the numbers from the computer, as he had been for most of the landing: "Thirty feet, two-and-a-half down. Faint shadow."

In Mission Control, there was silence except for a few callouts of critical bits of information. Everyone was glued to the radio transmissions, as there was no video of the landing. Then, another warning call from CAPCOM Duke: "Low level." The LM's landing stage was nearly out of fuel; it was now so low, the sensors could no longer measure it. Aldrin said, "100 feet," then, "Five percent," which was the estimated remaining fuel. They were nearing a point often referred to as the "Dead Man's Zone," the spot in the fuel-versus-time graph at which mission rules specified an abort if they could not land quickly. The problem with an abort at this altitude was that if they were too close to the lunar surface, nobody was sure that the LM could shed its descent stage and ignite the ascent engine fast enough to avoid becoming a few acres of smashed aluminum fragments, fluttering Mylar sheets, and two dead astronauts.

"CONTACT LIGHT"

As the *Eagle* flew laterally over the rugged surface below, Armstrong saw a relatively smooth, unobstructed area ahead, and steered toward it. Within moments, other than the radar data telling them of their altitude and speed, he was flying almost blind. The exhaust from the descent engine was slamming into lunar dust that had sat undisturbed for over a billion years, and creating a great, billowing particulate plume below them that completely obscured the surface. But he could see their shadow against the dust clouds, and that was guidance enough.

"Thirty seconds!" squawked in their headsets—an estimated half-minute before they would have to either be on the ground or abort. Aldrin took a quick moment to look away from the computer to glance at the "ABORT" button; he or Armstrong might be punching it within moments. In Mission Control, the silence seemed deafening, and many controllers were holding their breath. Though he didn't realize it until later, Kranz's grip was so intense that he snapped a pencil in his clenched fist. The crew should have landed minutes ago—they had never been this close to fuel depletion in any simulation.

A few hours prior, Kranz had taken a moment to steel his team before the landing attempt, saying: "Okay flight controllers, listen up. From the day of our birth, we were meant for this time and place, and today we will land an American on the Moon. Whatever happens here today, I will stand behind every decision you will make. We came into this room as a team and we will leave as a team. And from now on, no person will enter or leave this room until we have either landed, we have crashed, or we have aborted. Those are the only outcomes from this time on." Now, he desperately hoped that it would not be the latter outcome. In any case, they would know within moments.

Then the words they had all been waiting for rang out. Over the scratchy radio link, they heard Aldrin say, "Contact light." A five-foot long metal probe dangling from the LM's legs had touched the surface, and the craft landed just seconds later. They were down and safe. "Houston, Tranquility Base here ... the *Eagle* has landed," Armstrong said. The mission clock at the front of Mission

An early example of the maps used to plan the first lunar landing, as imaged by the Lunar Orbiter spacecraft. Credit: NASA

Control read 102 hours, 45 minutes, and 39 seconds since launch.

Eight years after President Kennedy had announced his challenge to the Soviet Union and the American people, to "land a man on the Moon and return him safely to the Earth," the first half of that objective had been realized. Two Americans were on the Moon, and the endless hours of sweat and toil by over 400,000 people had been realized in a moment.

IMMINENT DANGERS

As Armstrong and Aldrin busied themselves shutting down various systems in the Lunar Module to prepare for their 22-hour stay, relieved controllers and managers in Houston celebrated quietly even as they continued to monitor the complex systems that powered the fragile lunar lander. Immediately after landing, there had been some natural jubilation, but Kranz, after a moment of stunned shock, barked, "I want quiet in this room!" which was punctuated by his slamming his fist on the console so hard that within a day his arm was bruised up to his elbow.

Then, instrumentation on one of the consoles in Mission Control showed a disturbing indication: pressure in a fuel line in the LM's lower stage was slowly but inexorably rising. Tom Kelly, the Grumman engineer responsible for overseeing the design and fabrication of the lander, looked on with grave concern, as did the mixed team of engineers from that company and TRW, the contractor that had built the lander's descent engine. Although the landing was complete, and that rocket engine would never be used again (the ascent stage that would carry them home had a separate engine), if the pressure got too high in the descent stage, one of the fuel line fittings or a fuel tank could explode and cause a fire, potentially killing the crew instantly or crippling the lander. It was unlikely, but it was possible.

Engineers scrambled to come up with possible workarounds to relieve the pressure and Kranz tried to think five steps ahead. Should they "burp" the engine, relieving pressure but possibly causing other problems, or wait and see what happened? There was a component in the system that was designed to burst if the pressure rose too far, relieving pressure, but what if it didn't function as intended? Most immediately, should they tell the astronauts?

Before a decision was reached, the telemetry being received in Houston showed that the pressure had peaked and was now falling quickly—another potential crisis had been averted. Apparently, the cold of the lunar surface had caused a plug of ice to form in a fuel line; the residual heat in the descent stage had now warmed the engine sufficiently to cause the plug to melt.

A STICKY HATCH

After a few hours of rest and preparation, the two astronauts suited-up and prepared to descend the ladder to the lunar surface. The mission doctors had specified that the men sleep for a number of hours before this activity, but few had taken this instruction seriously—who could sleep after having just set down on the Moon? On the spot, Armstrong requested that they change this to a short rest period, and get on with the exploration that they had come so far to perform. Mission Control agreed, and a few hours later, Armstrong and Aldrin donned their Extra Vehicular Activity (EVA) suits, cross-checked the fittings and the function of their life-support backpacks, and prepared to explore the Moon. The next step was open the hatch and leave the lander.

They opened a small valve to vent the air pressure out of the cabin so that the inward-opening hatch would swing free, waited for the oxygen to vent out, and then waited some more. There was a filter installed to prevent stray bacteria from leaving the LM, and this slowed the venting process. After a few minutes, the gauge had bottomed out and Aldrin turned the latch handle and pulled, but the hatch would not open. He tugged and tugged, but it remained stubbornly closed. Coming all this way only to be vexed by a stuck hatch was unimaginable.

Other options were considered—there was a second vent near another hatch at the top of the LM used for docking—but rather than use that, Aldrin tugged on the hatch some more, but carefully... nobody wanted that handle to break. After a frustrating few minutes, Aldrin grasped the corner of the balky hatch and bent it back a bit—it was that thin—and with a whoosh, the remaining atmosphere escaped the LM in a shower of icy particles. The hatch swung inward, and Armstrong got on his hands and knees in preparation to crawl out.

AND A BROKEN SWITCH

As Armstrong struggled into position to exit the hatch, neither he nor Aldrin heard the dull snap of a switch breaking in the vacuum; it was the circuit breaker that they would later use to arm the ascent engine to return home. The broken plastic stud fell silently to the floor of the cabin, and they would not discover this until they returned to the lander after their excursion outside.

Armstrong squirmed carefully out of the hatch and descended the ladder, stopping at the base to make sure that he could make the jump back up to the lower rung when it was time to return. Then, six minutes after he cleared the hatch, Armstrong was stepping off the lander's footpad and onto *luna incognita*.

"That's one small step for [a] man, one giant leap for mankind." What everyone on Earth heard was, "That's one small step for man," yet Armstrong had intended to say, and thought he had said, "a man." The topic has been debated endlessly, studied by linguists and audiologists, and the recorded words parsed by modern computer programs, yet a definitive answer still eludes us, and that's okay. It's enough to know what Armstrong had intended to say.

Upon stepping onto the dusty plain of *Mare Tranquilitatis*, Armstrong's first assigned duty was to grab a "Contingency Sample." He was supposed to use a scoop to gather a bit of lunar rock and dirt, right there near the lander, and deposit it into a small bag. That way, if something untoward occurred that caused the astronauts to make a hasty reentry into the LM and an emergency liftoff, NASA would at least have a little bit of the Moon as a consolation prize.

Armstrong didn't do that and, to the brief consternation of the geologists and mission planners, he was silent for a time. CAPCOM Duke reminded him that he should be getting his sample, to which Armstrong replied, "Roger, I'm going to get to that just as soon as I finish these ... picture series." He had noticed that the ladder side of the LM where he stood was in shadow, and felt that getting a series of photos in that light would be beneficial. It would not be the last time during the Moonwalk that his scientific curiosity would override Houston's plans.

Aldrin joined him on the surface about 18 minutes later, uttering what may have been the most poetic words from the entire Apollo program, saying simply, "Magnificent desolation," as he took in his first panoramic view of the Moon.

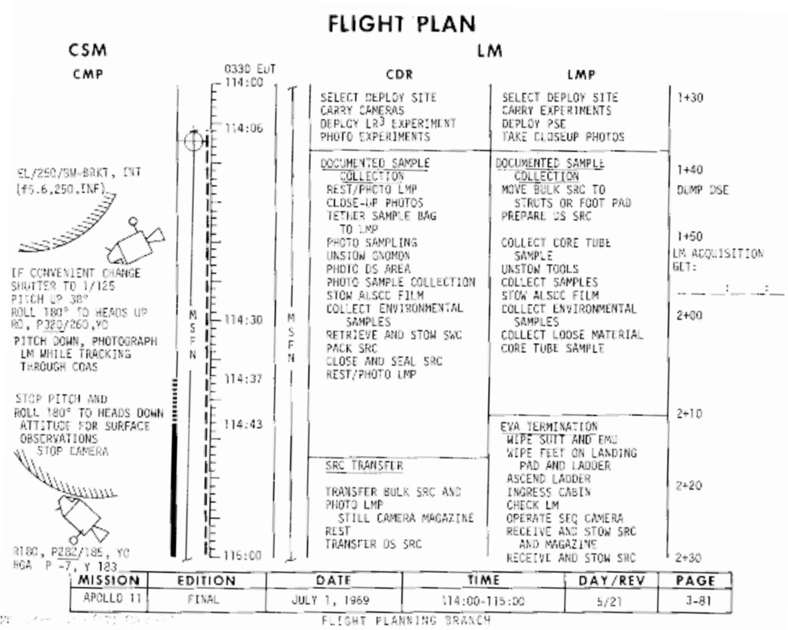
During the next two and a half hours, the duo conducted the first reconnaissance of the Moon, an almost frenzied exploration that attempted to pack a day's worth of work into just a couple of hours. On Earth, an estimated 600 million people watched as ghostly images showed two Americans exploring beyond the edge of any map, daring to do what had seemed impossible just a decade earlier.

After the ceremonial duty of unveiling the commemorative plaque on the *Eagle's* front leg, the two astronauts began unpacking the equipment from the LM's descent stage that would be deployed on the lunar surface. Then came a surprise event: the most expensive phone call in history.

President Nixon was not about to lose his opportunity for a "press moment" with the astronauts on the Moon. Astronaut Frank Borman, who had flown on Apollo 8, was the White House liaison for NASA, and suggested that the president make a brief call to the astronauts while they were on the Moon. Nixon agreed. Mission Control patched Nixon through to their audio feeds. The president's image was shown in split-screen by the television networks back home. Though the call only lasted about two minutes, it cost the program millions of dollars—but that's politics.

In just over a year, Nixon would approve the cancellation of Apollo 18, 19, and 20, for which hardware had already been built. Some of the rockets and spacecraft were sent to museums, while others were repurposed for missions such as Skylab and the Apollo-Soyuz Test Project.

As the Moonwalk progressed, Armstrong focused on gathering samples while Aldrin made an extensive photographic survey of the LM and the landing site. Armstrong had been instructed not to travel beyond the range of the television camera so that Mission Control could visually monitor his progress, but that limitation did not last long. Endlessly curious, Armstrong loped further and further from the LM as he saw what appeared to be promising areas for sample collection. While mission managers worried over the expanding range of his activities, Lee Silver,



The lunar surface activities as documented in the Apollo 11 flight plan. Note that to the lower right, the astronauts are instructed to reenter the Lunar Module at two hours plus twenty minutes—Mission Control eventually gave them extra time to explore.
Credit: NASA

a Caltech geologist working in a back room at Mission Control, marveled at how well this former test pilot, hastily-trained as a geologist, was performing his scientific chores.

"What Neil did in the shortest period of time that anybody [had] was so brilliant from this point of view of providing the

Aldrin setting up the EASEP experiment.
Credit: NASA

materials to the scientists, that nobody can claim to have exceeded it in production per minute. He was really outstanding." NASA had given Armstrong "a very strict protocol," Silver said, "which said, 'You will never leave the field of the [television] camera.' Neil Armstrong recognized that just beyond the field of the camera was a rim of craters covered with rocks and dust, which had been excavated from a little deeper than everywhere else, and he had a very special box for bringing back good samples with a special seal on it, and for about seven or eight minutes, you couldn't see Neil." In the end, nobody called him out on it; Armstrong was just doing good science.

Meanwhile, Aldrin began what would be a time-consuming struggle to set up the experimental package destined to be left on the Moon. The EASEP, or Early Apollo Scientific Experiment Package, contained a seismometer, a lunar dust collector, and a radio for transmitting data back to Earth after the astronauts departed from the Moon. It seemed simple enough to erect. The package was designed to be set on a flat surface and then unfold and snap into place, but finding that flat surface turned into a vexing chore.

The EASEP had a simple device that was supposed to make it easy to level once placed onto the lunar soil. This consisted of a small cup with a clear plastic cover and a metal bead that was supposed to roll to the center when it was flat. Aldrin swore that the cup had somehow inverted, or at least it looked that way to him, and felt that he was wasting time trying to level the unit with little success. Try though he might, the little ball rolled defiantly around the outer rim, avoiding the center where it belonged. Frustrated, he radioed Houston.

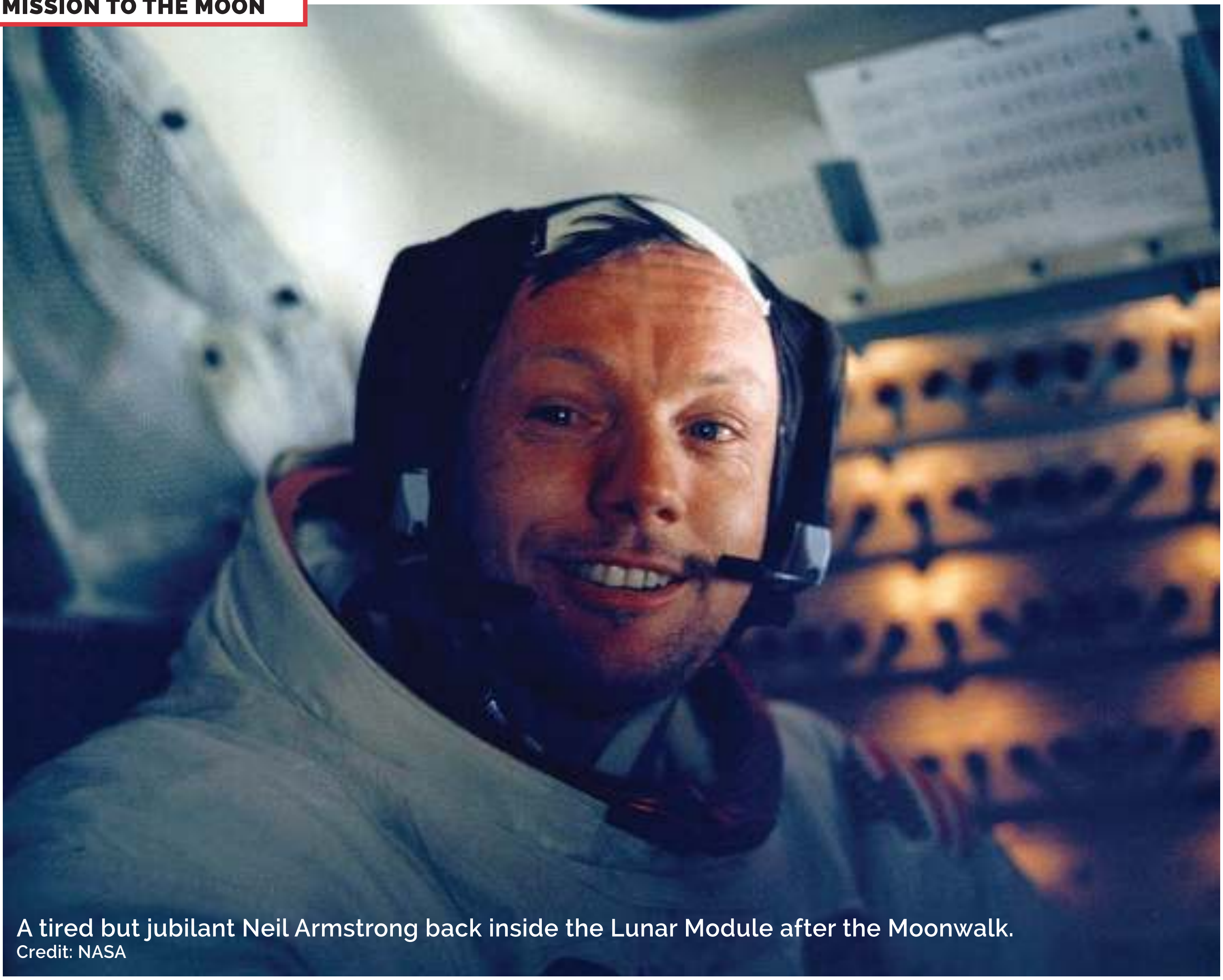
"Houston, I don't think there's any hope for using this leveling device to come up with an accurate level. It looks to me as though the cup here, that the BB is in, is now convex instead of concave. Over." CAPCOM Duke responded, "Roger, 11. Press on. If you think it looks level by eyeball, go ahead."

A few minutes later, Houston asked for a photo of the troublesome leveling device on the EASEP for future reference. Since Armstrong had the only camera between them, he volunteered to take it. "Oh, shoot! Would you believe the ball is right in the middle now?" he exclaimed when he snapped the shot. A disgruntled Aldrin responded, "Wonderful. Take a picture before it moves!"

By now they had already been working outside the LM for about two hours and 12 minutes, and were nearing the end of the time alloted for their Moonwalk. However, there was still much to be accomplished before they went back up to the waiting ascent stage. When Mission Control advised them they were close to the end of the Moonwalk, they softened the blow by adding 15 minutes to the scheduled termination.

Armstrong had yet to gather the "Documented Sample," in which he would carefully record the area from which he gathered each bit of rock and soil with photos and labels on the sample bags. Aldrin was elsewhere, trying to get a core sample. By now the astronauts were no longer walking from place to place, they were running to-and-fro, trying to meet all their objectives.

As Armstrong scooped up bits of the Moon and made notes, Aldrin was struggling with the core sample tube. The surface was



A tired but jubilant Neil Armstrong back inside the Lunar Module after the Moonwalk.
Credit: NASA

harder than anticipated, and he was pounding the collection tube into the soil as hard as he dared. No matter how hard he struck the tube with his geology hammer, it only went down a couple of inches. Aldrin radioed down, "I hope you're watching how hard I have to hit this into the ground, to the tune of about 5 inches [13 centimeters], Houston." Toward the end the exercise, he was raising his hammer to the height of his helmet to exert enough force to drive the tube deeper. The final result netted about two inches of lunar soil, far less than was desired, but it would have to do.

After just over two-and-a-half hours outside the *Eagle*, with Aldrin already back inside, Armstrong headed up the ladder. He and Aldrin had used a conveyor rope—called "the clothesline"—to move their cameras, film packs, and lunar samples up to the ascent stage of the module. At 111 hours and 39 minutes mission elapsed time, they were back inside with the hatch closed. By the time it was all done, the interior of the LM was covered in lunar dust; the sample containers and spacesuits, despite their best efforts, had carried a lot of it inside.

As the LM repressurized with oxygen, the two astronauts chuckled, noting that their EVA suits had not caught on fire. Long before departure from Earth, Thomas Gold, a physicist from Cornell University, had suggested that lunar dust on their suits might combust when exposed to oxygen. He had also suggested that the Moon might be covered in such deep dust that the heavy LM could sink out of sight upon touchdown. Gold had been part of NASA's spaceflight planning since the late 1950s and his opinions carried some weight at the agency, though few took these particular notions very seriously. In the end, neither hypothesis was correct. The astronauts did notice, however, that lunar dust—which now covered the interior of the cabin in a fine silt—had a peculiar smell, one that Aldrin likened to spent gunpowder.

They removed their backpacks and hooked their suits up to the onboard life support system, then reopened the hatch and tossed out unneeded items to lighten the ascent stage for liftoff. Out went the backpacks, the cameras, and anything else that was not necessary for completion of the mission. Soon the area around the front leg of the LM looked like a trash heap, but it could not be helped—any additional weight would jeopardize their chances of a perfect launch.

Also left behind were commemorative medallions bearing the names of the three Apollo 1 astronauts who lost their lives in a launch pad fire in the prior year, and two cosmonauts who also died in accidents. The medallions had been carefully placed on the lunar surface during their Moonwalk, along with a one-and-a-half inch (3.5 centimeter) silicon disk, containing miniaturized goodwill messages from 73 countries, and the names of congressional and NASA leaders.

The astronauts had a rest period that included seven hours of fitful sleep before they arose and prepared to depart the Moon. But there was one major issue that needed to be resolved before they could leave: that broken switch. Before the astronauts went to sleep, they discovered the little plastic tab on the floor of the LM and informed Mission Control. For the next few hours, engineers in Houston worked on various ways to bypass the circuit controlled by the switch, which was critical for arming the ascent engine. If it did not fire, Armstrong and Aldrin would remain on the Moon—permanently.

After all the fuss by the engineers on the ground, Aldrin looked at the switch, took a felt-tip pen from his pocket, and jammed it into the socket, tripping it—a problem solved for about 39 cents.

After completing a checklist, the two suited up, entered the requisite commands into the guidance computer, and counted down. In just milliseconds, explosive bolts separated below them, a guillotine sheared a four-inch bundle of wire that connected the ascent stage to the descent stage, and the ascent engine fired. The top half of the LM took flight quickly, scattering fluttering bits of Mylar all over the landing site and knocking over the carefully planted flag. “We’re off. Look at that stuff go all over the place,” Aldrin said, referring to the Mylar detritus. “Look at that shadow. Beautiful.”

Three hours later, Armstrong and Aldrin were closing on the *Columbia*, where Michael Collins awaited them. After a successful docking, they transferred their lunar bounty into the Apollo capsule, sealed the hatch, and released the *Eagle’s* ascent stage, sending it on its way.

At that moment on Earth, Tom Kelly, who had been at Mission Control for most of the mission, felt a twinge. The first Lunar Module to land on the Moon had completed its task and passed with flying colors. The undocking represented the final act for the complex little ship, and he could not have been prouder. Kelly later reflected that the LM’s contribution to the Apollo program “showed us what people could do in space under some very demanding conditions… I was delighted to work on it and really very happy that it went as well as it did.”

Five hours after that, Collins fired *Columbia’s* main engine to break free of lunar orbit and send them on their way home, where they would be kept in biological isolation for three weeks to assure that they had not brought home any “Moon germs.” Once cleared by the Centers for Disease Control, they left their isolation unit and entered the history books.

Five more Apollo missions would accomplish increasingly ambitious explorations of the Moon. Each one went to ever-more interesting and progressively more challenging landing sites to explore Earth’s satellite, and all were successful in meeting their objectives, except for Apollo 13. That mission was later dubbed a “successful failure,” with the crew of the stricken spacecraft returning home safely without landing on the Moon. But daring though they all were, none of these missions were as impressive to the world as that first lunar landing, the flight of Apollo 11.

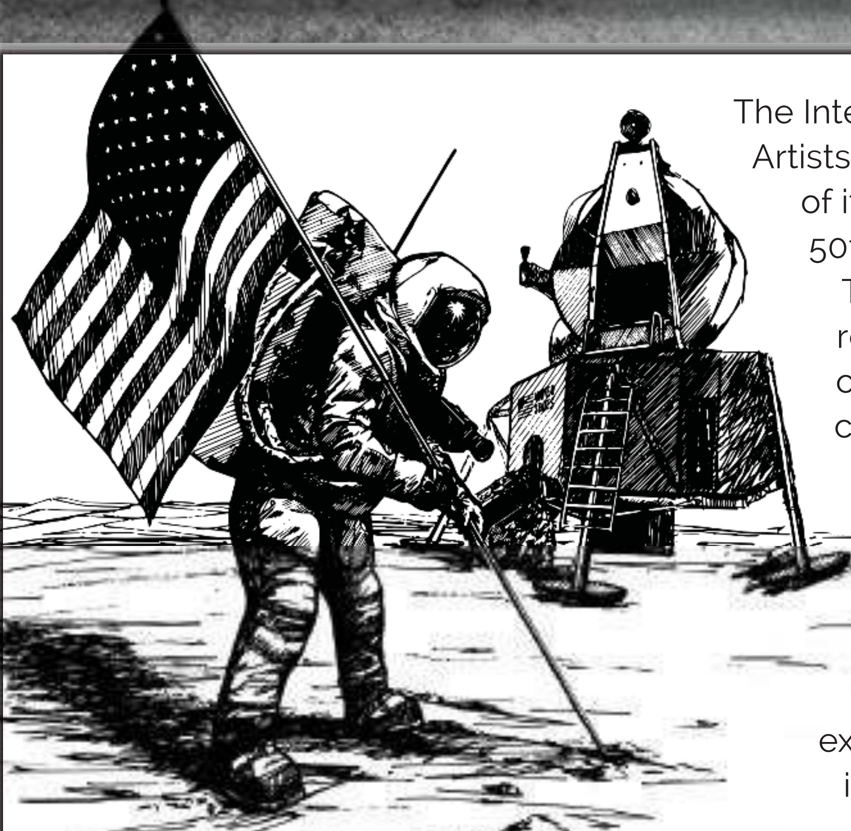
At just over 135 hours into the mission, Collins fired the engines on *Columbia* that broke the spacecraft free from lunar orbit and sent them onto a course for Earth.
Credit: NASA

A NEW GENERATION OF APOLLO ART:

Inspirations from the International Association of Astronomical Artists.

Mark Maxwell

"Legacy"



The International Association of Astronomical Artists (IAAA) is pleased to showcase some of its members' artwork celebrating the 50th anniversary of the Apollo program. The selected works presented here represent just a small sampling of the offerings created by IAAA members to commemorate the legacy of the Space Age. Founded in 1982, with members from all over the globe, the IAAA's mission is to promote space art, STEAM education, and to foster international cooperation in artistic projects inspired by the exploration of the universe. For more information, visit: https://iaaa.org.

Aldo Spadoni

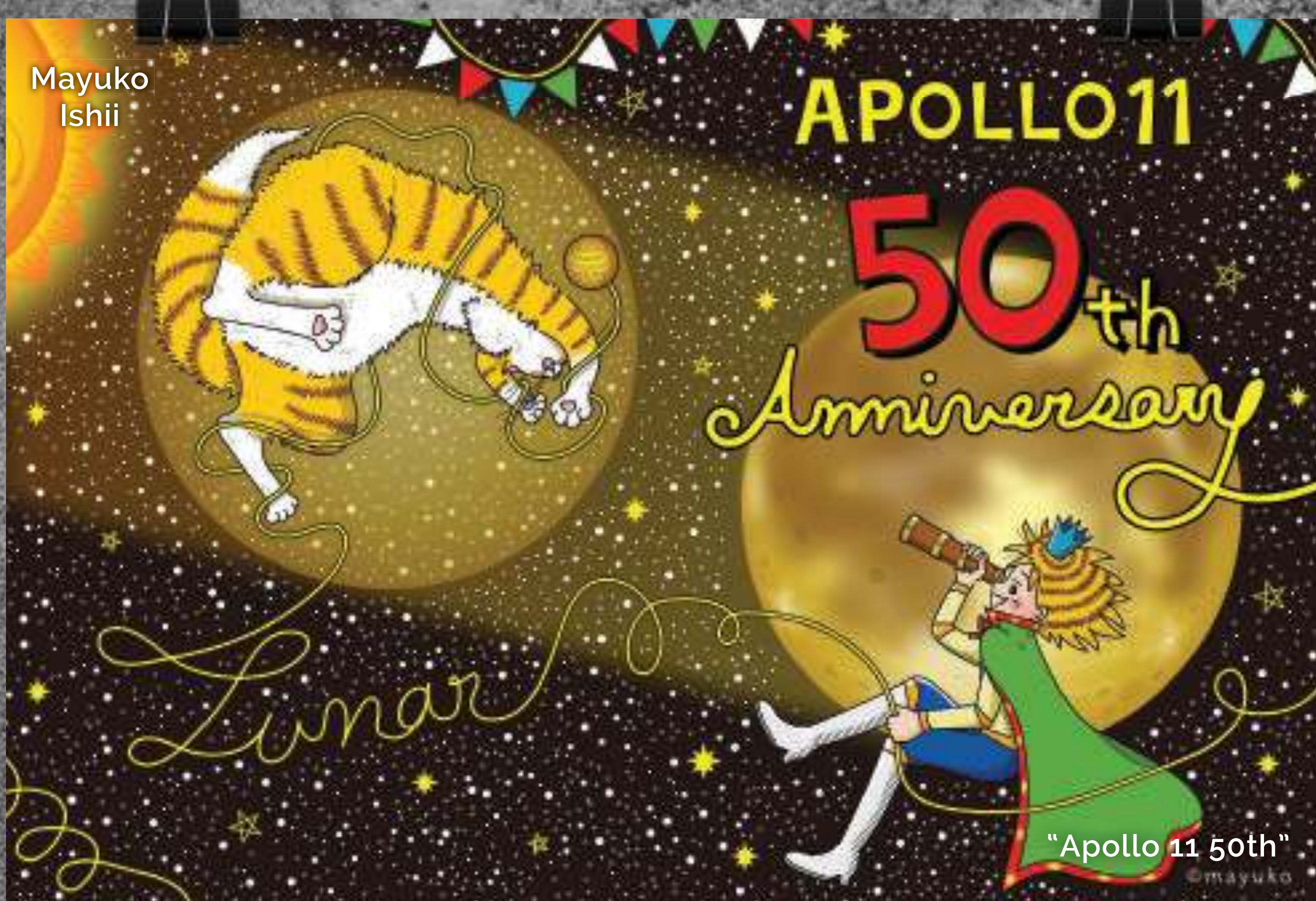
"Saturn V Ascending"

Lucy West

"Discovering Earth"

Mark Garlick

"Apollo CSM Above the Moon"



Mayuko Ishii

"Apollo 11 50th"

Simon Kregar

"LEM"

Doug Forrest

"Jim McDivitt"

Marilynn Flynn

"The Astronaut's Book of Hours–Apollo"

THE CHILDREN OF APOLLO

Rod Pyle

Typical suburban sprawl outside the Johnson Space Center near Houston, Texas. It was in neighborhoods like these that the astronauts and their families lived during the space race. Credit: Wikipedia

"I didn't understand all the attention, either good or bad, that I was getting—I didn't think I had done anything to deserve it."

—Rick Armstrong, son of Neil Armstrong

To the children of the Apollo astronauts, growing up in the new suburbs outside the Johnson Space Center seemed normal. Upon later reflection, however, it was anything but ordinary. This book excerpt contains the recollections of Rick Armstrong and Andrew Aldrin.

The suburbs around Houston, Texas and the Kennedy Space Center in Florida were brand-new, tight-knit communities, where many astronauts and their families rubbed elbows with thousands of family members of others working on the space program.

While kids were kids—playing football, delivering newspapers, and going to school—being the child of an astronaut was somewhat different, though many of the astronauts' children did not really realize it at the time.

Each of the three Apollo 11 astronauts had three children. Armstrong had two sons and a daughter (sadly, the daughter died as a child), Aldrin had two

Andrew Aldrin presents at a conference. Credit: NSS

sons and a daughter, and Collins had two daughters and a son. Each of them responded differently to life in the limelight as the children of the first crew to attempt a Moon landing.

ANDREW ALDRIN

Andrew "Andy" Aldrin was born in the same year as NASA, 1958. His career path has ranged from executive positions at Boeing and United Launch Alliance to serving as president of Moon Express, a small startup in Northern California that aims to land the first private robots on the Moon. He ran the Buzz Aldrin Space Institute, which was founded to advance space exploration and development, and is currently an associate professor at the Florida Institute of Technology. While his life has taken him into aerospace as a profession, as a boy he was more interested in football than spaceflight. He describes a sense of normalcy that surrounded his childhood:

> I grew up in Nassau Bay, [Texas] which was somewhat of an astronaut enclave, so it was normal to have your dad going to the Moon or into space. My elementary school was filled with astronauts' kids. Dad was busy, and he was gone a lot, but that was his job. Where we lived, the vast majority of the people worked at NASA, and at that time, working at NASA was not a forty-hour-per-week job. So I didn't really grow up wishing my dad was home more often like everybody else's dad, because everybody else's dad was working the same kind of hours.

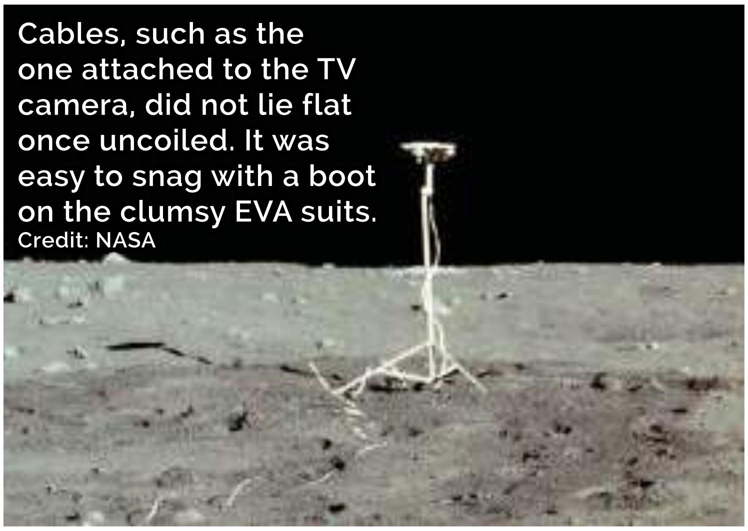
He remembers his father preparing for Gemini 12:

> I was seven or eight when my dad flew on Gemini 12. I knew that they had experienced problems with the EVAs on the Gemini missions a few months before my dad's mission, but I didn't really understand how hard he was working to close that gap on Gemini 12. I was, however, very aware of the spacewalks and the work he had done with underwater training to prepare. Heck, when I was six, dad threw me in the pool with a scuba tank for the first time. It wasn't anything relevant to EVA—I think he just wanted to share his fascination with underwater training!

Andy was 11 years old when Apollo 11 launched. Regarding the danger of the mission, Aldrin says, "Aside from the fact that I got to crash the lunar simulator over at NASA, I really didn't have a good idea of the risks involved in that first landing. What *did* worry me was the ascent engine on the LM ... But as for the rest of it, I assumed that it would all work. Now I understand just how dangerous it was, of course." His memories of the Moonwalk are more specific:

> My most distinct memory is of my dad hopping around on the Moon. And I knew why he was doing this … he was trying to understand the most efficient way to locomote while on the Moon. So he's doing this lunar bunny hop, and I'm fixated on this cable, stretched between the LM and one of the experiments or the TV camera, and I'm just sure my dad's going to trip over that cable and end up flat on his back. I wasn't really worried about him, you understand—I knew that NASA's technology was top-drawer. But if he tripped over that cable in front of hundreds of millions of people watching on TV, and most importantly, my two hundred classmates at school, that would be terrible. I was scared to death not that he might die, but that he might embarrass me. That's what goes through an eleven-year-old's mind when your dad is walking on the Moon.

Andy closed his interview with a comment about his father's ongoing passion for spaceflight: "It's absolutely his life's work, and nothing is more important. He never stops thinking about it. For my dad, it's a personal passion."



Cables, such as the one attached to the TV camera, did not lie flat once uncoiled. It was easy to snag with a boot on the clumsy EVA suits. Credit: NASA

ERIC ALAN "RICK" ARMSTRONG

Rick Armstrong may have spent his childhood in the shadow of the Moon, but it was Earth's oceans that called to him professionally. After majoring in biology at Wittenberg University, he worked as a marine-mammal trainer for a few years and then went to work for the U.S. Navy in Hawaii. For the past couple of decades, his professional life has revolved around software and database design. He remembers his father, Neil, as similarly academic, yet with a sense of humility that has become legendary: "Dad read extensively and was very knowledgeable in a great many subjects, yet he wasn't afraid to admit that he

Rick Armstrong poses with a painting of his father at Edwards Air Force Base in 2014.
Credit: NASA/USAF

didn't know much about whatever the topic of the conversation was, if that was the case." He says his father described himself as a "white-socks, pocket-protector, nerdy engineer."

While Rick remembers some of the Gemini 8 flight, he knows that it was the X-15 that really got his father engaged in going out beyond the blue sky. "Dad held his time in the X-15 program in very high regard," he recalls. Armstrong worked closely with the engineering team on development of the X-15 flight systems and made seven flights in the rocket plane from December 1960 through July 1962. "He thought of these as team accomplishments rather than personal achievements," Rick says.

Rick's experience growing up was similar to Andy Aldrin's. "I never thought our family life was different than other families'. His job was always as a pilot or astronaut," he recalls. "It was a normal suburban life ... It wasn't until later, when I was in college, that I realized what a profound effect my father had on society. It was a bit of a shock, and rather humbling."

The perilous Gemini 8 mission was just part of his father's work, and Rick's father rarely spoke of it. "I'd ask dad about work, and he didn't say much ... He did mention that the Gemini mission had been a challenge and required himself and Dave Scott to do some intense flying. But in general, that was about as dramatic as he would get when discussing such things." That was as humble a response to the near-disaster of Gemini 8 as can be imagined. "I did not understand at the time how much trouble Gemini 8 was in. [It] wasn't really until years later that I understood how bad it was, and how close they came to dying."

Neil Armstrong's advice to his son? "Work hard, do your very best, and respect your neighbors." It would take these characteristics, and much more, for Neil Armstrong and Buzz Aldrin to pull off the first lunar landing. Rick Armstrong's memories of that time revolve more around school. "I don't think school in Houston was much different, at least I didn't notice it. It wasn't until we moved away from Houston [after the mission] that it changed ... I didn't understand all the attention, either good or bad, that I was getting—I didn't think I had done anything to deserve it." As he recalls:

> I was old enough to know what was happening but not old enough to understand the complexity and risk. It was just what they [the astronauts] did; it was their job. We knew it was dangerous, but lots of kids in that neighborhood had dads with dangerous jobs. I never had any doubts or fears because I was sure everything was going to work, or if it didn't, they would figure something out to fix it.

For Rick Armstrong, watching his father walk on the Moon was no big deal—perhaps because of his father's humility. "I really don't remember specific thoughts during the Moonwalk," he says. "It was just cool watching it. I knew it was my dad up there, and he seemed to be doing fine. I think we had every confidence that he would come home safe."

Armstrong in training on April 22, 1969.
Credit: NASA

This article was excerpted from the new book "First On the Moon: The Apollo 11 50th Anniversary Experience" by Rod Pyle with a foreword by Buzz Aldrin. Published by Sterling Books in association with the National Space Society.

AND DON'T FORGET...

Clifford R. McMurray

Credit: NASA

ONE IN THE COMMAND MODULE

While we hear much about the astronauts that walked on the Moon, there was a third crewmember on each Apollo mission that was critical to success: the Command Module Pilot, without whom none of the Apollo missions would have accomplished its goals.

Mike Collins during a simulation inside the Command Module *Columbia*.
Credit: NASA

Minutes after Apollo 11 landed on the Moon, CAPCOM Charlie Duke told Neil Armstrong, "Be advised there's lots of smiling faces in this room and all over the world."

"Well there are two of them up here," Armstrong replied. Michael Collins, orbiting overhead, was smiling too as he keyed his microphone to say, "And don't forget one in the Command Module."

Unfortunately for Collins, the two-and-a-half second round trip time for a radio signal meant that a reply was coming in from Houston at the same time: "Roger. That was a beautiful job, you guys."

"I was more than a little embarrassed to hear their message coming in as I was mouthing mine. It sounded like I was asking them not to forget to compliment me ... instead of merely adding my smiling face to the list," he wrote later.

Embarrassing miscommunication aside, Collins' words could properly be taken as the legitimate complaint of every Command Module Pilot (CMP) who came before and after him in the Apollo program. There are library shelves full of books written by and about the Moonwalkers; only three CMPs—lunar astronauts who did not make the trip to the surface—have had biographies or autobiographies published about them. As Armstrong himself said, "The Command Module pilot, the second in command of an Apollo spacecraft, was the least understood and least appreciated crew member by the media and the general public." Collins won't be forgotten because he was a member of the first crew, but hardly anyone who's not a certified space geek can name even one of the others. As one recent commentator put it, they were "the drummers in the Apollo rock band."

They had to fly the Command and Service Module (CSM) single-handedly. Not since the Mercury missions, and never again, would any astronaut fly a spacecraft alone. They were spacecraft pilot, navigator, and engineer all rolled into one, and the CSM was a very complicated spacecraft. "I'd say the Command

Ron Evans, the Command Module Pilot on Apollo 17, retrieves a film magazine from the Service Module instrument bay.
Credit: NASA

Module, although it's a lot smaller, probably is about as complicated as a B-52 bomber, which has a crew of six," Collins said, comparing it to the jets he'd flown in the Air Force and contemplating the "great handfuls of switches" on the control panels that surrounded him. The checklist for firing the engine on the Service Module, per fellow astronaut John Young, listed 72 separate activities, including verification of switch positions, arming of circuit breakers, and computer inputs.

As the navigators for their crews, the CMPs had to master the esoteric base-eight programming language of the Apollo Guidance Computer, and feed it with correct inputs from the onboard sextant. Over the course of many trips to the Morehead Planetarium at the University of North Carolina in Chapel Hill, North Carolina, they became intimately familiar with the constellations and the 37 guide stars used by the computer to determine their position from the time they reached Earth orbit until they splashed down in the ocean. They were also responsible for rendezvous and docking operations, and had to be ready to rescue their crewmates from any erratic orbit the Lunar Module (LM) might have put them into. For the first lunar landing, the possible rendezvous scenarios were boiled down to 18 cases which Collins kept in a book tethered around his neck the whole time Armstrong and Aldrin were flying in the LM.

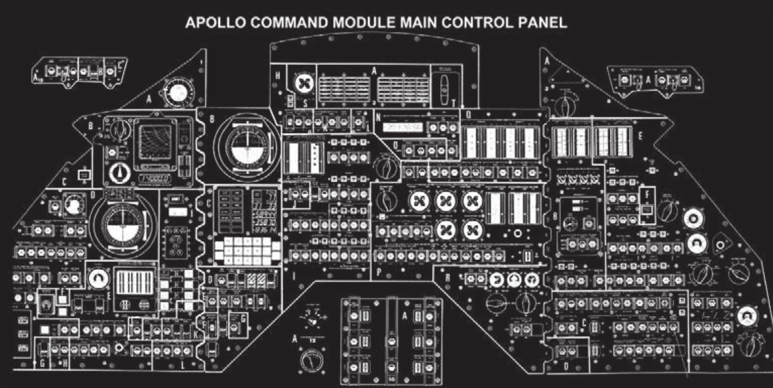
There were, of course, some scenarios in which nothing the CMP could do would save his companions. If the LM's ascent engine didn't fire, his two crewmates would be stranded with no possibility of rescue, and he would have to come home alone. Collins called that outcome his "secret terror."

During their time alone in lunar orbit, the CMPs were the most isolated humans in the universe, but they didn't feel lonely. "There's a thing about being alone and there's a thing about being lonely, and they're two different things," said Al Worden, the CMP for Apollo 15. "I was alone, but I was not lonely... I thoroughly enjoyed it." He continued, "On the back side of the Moon I didn't even have to talk to Houston, and that was the best part of the flight." The stars kept him and the other CMPs company; they all remarked on the view seen during that part of the orbit, with no sunlight or light from Earth to interfere. The stars were so numerous that it was hard to recognize the constellations. "It was like a sheet of light," said Worden, adding "You want to feel insignificant? Go behind the Moon sometime."

Collins had similar thoughts. In his autobiography "Carrying the Fire" he wrote, "I don't mean to deny a feeling of solitude ... I am alone now, truly alone, and absolutely isolated from any known life. If a count were taken, the score would be three billion plus two over on the other side of the Moon, and one plus God only knows what on this side. I feel this powerfully—not as fear or loneliness—but as awareness, anticipation, satisfaction, confidence, almost exultation. I like the feeling."

The CMPs on the first lunar flights had a relatively light load of photographic and observational tasks, but starting with Apollo 13 they were trained to contribute more to the scientific return of the mission. Harrison Schmitt, the only geologist among the Apollo astronauts, was their first teacher, but soon they were handed off to an Egyptian-born geologist named Farouk El-Baz. "Anyone can look," El-Baz told them, "but few can really see." Under his enthusiastic tutelage, they learned how to see. They were excited at the prospect of being remote geological observers from their unique vantage point, and came to know the Moon's geography better than their crewmates. The photographs that Stuart Roosa brought back of the Descartes Highlands were instrumental in picking that area for the Apollo 16 landing, and Al Worden's pictures and excited descriptions of what looked like volcanic craters at Taurus-Littrow closed the case for making that the Apollo 17 landing site. Hearing from Mission Control that "the King," as they nicknamed El-Baz, was pleased with their work was for each of them a moment of special pride.

For all the Apollo lunar flights through Apollo 14, the CSM stayed in a roughly circular orbit about 60 miles above the lunar surface while the LM made its descent. But the last three lunar missions,



The control console of the Command Module–complex, yet elegant.
Credit: NASA

which NASA called J-class missions, were longer and more ambitious. The LMs got heavier, with more scientific equipment and an electric rover enabling them to cover more territory, and more oxygen and other supplies to enable staying on the surface for up to three days. To compensate for the additional weight, the CSM engine was used to put the LM in an elliptical orbit that came within only about 10 miles (16 kilometers) of the surface, saving fuel in the LM for the final descent. That put the last three CMPs tantalizingly close to the big prize. Worden holds the record among them; he got within just 7.6 miles (12.2 kilometers) of the surface at one point.

Apollo 15, 16, and 17 also had an expanded science program for the CMPs to run while their companions explored the surface. One of the equipment bays of the Service Module was fitted with a suite of cameras and sensors to map the Moon at high resolution and determine its chemical composition. Those cameras were supplemented with handheld photography by the astronauts. Apollo 15 and 16 even had small satellites for them to launch, which measured charged particles and magnetic fields around the Moon. The CMPs, as competitive as their crewmates, were determined to maximize their science return, and inevitably overscheduled themselves. Ken Mattingly found himself too busy to eat, except when occupied with other bodily functions, while Al Worden worked 20-hour days and got by with only three or four hours of sleep per night.

The cameras in the Service Module were not digital, and the need to retrieve their film cassettes afforded the last Apollo CMPs a unique experience: to date, they are the only astronauts who have performed spacewalks in deep space. On the first of these spacewalks, Al Worden regretted not having a camera to capture what he thought could have been a picture even more famous than Apollo 8's iconic Earthrise photo: his crewmate Jim Irwin standing in the hatch of the capsule, perfectly framed by the Moon behind him. "It looked as big as the spacecraft, and was dramatically lit by the sun, emphasizing the rugged craters. I could even see myself, floating in space, reflected in Jim's visor."

Deke Slayton, as Director of Flight Crew Operations, selected only astronauts who had experience in rendezvous during Gemini flights as CMP pilots. As the program progressed, pilots from later astronaut classes were put into the flight rotation, with those from lunar flights commanding first a backup crew and then a prime crew for later landings. Dave Scott and John Young were the only two CMPs to make it to the lunar surface before Apollo 18, 19, and 20 were cancelled. Slayton offered Collins a commander's slot as well, but Collins decided Apollo 11 was enough for him. The newer astronaut class had come just a little too late to the party; Collins himself was part of the third group to be accepted as Apollo astronauts.

Of course, they all would have liked to walk on the Moon. They were every bit as skilled as the astronauts who did, and their life stories are just as compelling. Missing those last few miles was, said Mattingly, "like going to a wedding and being the bridesmaid," but the CMPs were team players who had the satisfaction of knowing that the team couldn't function without them. Orbiting the Moon without landing may have not been the big prize, but was still a staggering achievement by any measure.

Geologist Farouk El_Baz, at right, works with Apollo CMP Ron Evans. Future shuttle astronaut Robert Overmyer is to far left.

APOLLO COMMAND MODULE PILOTS

Apollo 7	Donn F. Eisele
Apollo 8	James A. Lovell Jr.
Apollo 9	David R. Scott
Apollo 10	John W. Young
Apollo 11	Michael Collins
Apollo 12	Richard F. "Dick" Gordon Jr.
Apollo 13	John L. "Jack" Swigert Jr.
Apollo 14	Stuart A. Roosa
Apollo 15	Alfred M. Worden
Apollo 16	Thomas K. "Ken" Mattingly II
Apollo 17	Ronald E. Evans

APOLLO'S LEGACY

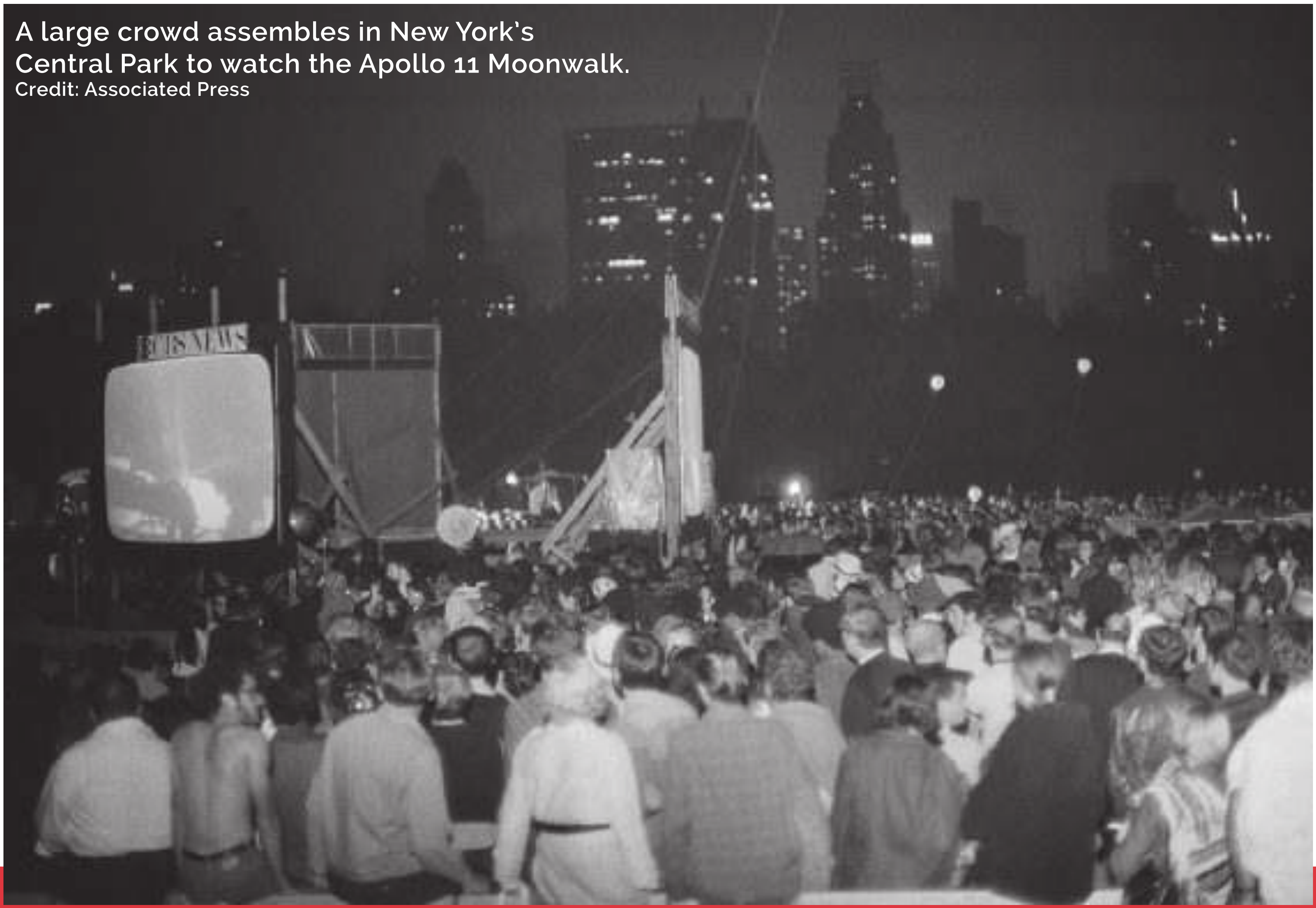
One Giant, 50-Year Leap:

Anthony Paustian, Ph.D.

HOW APOLLO'S STORY CAN HELP FIX NASA'S CURRENT BRAND PROBLEM

Girl reading a newspaper detailing the events of Apollo 11.
Credit: Wikipedia

A large crowd assembles in New York's Central Park to watch the Apollo 11 Moonwalk.
Credit: Associated Press



Imagine an organization with a name recognized in every country in the world, whose every move was watched by hundreds of millions of people, and whose successes fulfilled the dreams of a nation and inspired awe and admiration around the world. This was NASA in the 1960s. How can the space agency revive it's "brand" in the 21st century?

I was five years old when Neil Armstrong and Buzz Aldrin became the first men to land on the Moon during the flight of Apollo 11. Like many people, I watched the event on a black and white television, and then went outside to look up at the Moon, knowing that people were exploring its forbidding terrain. For the millions of children across the globe who were inspired by that occurrence, this was a defining brand moment for NASA.

The Apollo program set a new and dramatic benchmark for our abilities as a nation. If we can go to the Moon, we thought, then what other feats long considered impossible could we accomplish? While President Kennedy's 1961 announcement to send humans to the Moon was primarily political, it became a driver for imagination, scientific discovery, and engineering.

The research and development underpinning the Apollo program presented many challenges that called for new solutions. These solutions influenced the growth of high-technology industries and ultimately thousands of products were spun off into new commercial markets, such as semiconductors and computers, microwave ovens, batteries, cordless power tools, kidney dialysis machines, MRI and CAT scans used in healthcare, solar panels, fire-retardant fabrics, polarized sunglasses, water purification, advances in food preservation, improved satellites, and more. Studies indicate a societal return on investment as high as 14 dollars for every dollar spent, causing the returns on most other


An image of the Apollo 11 Moonwalk captured from a live feed in 1969.
Credit: NASA

forms of investment to pale in comparison.

Despite Gallup's research showing that over half of the American public didn't want to fund the lunar landing goal, the Moon landings boosted the level of national pride as an estimated 600 million people came together for a brief moment to watch the events unfold on television. This was no small feat considering that the country was still dealing with repercussions related to the assassinations of President Kennedy, his brother Robert, and Martin Luther King, Jr. We were also mired in an unpopular war in Vietnam, facing the possibility of nuclear annihilation, challenged by a stagnating economy, and dealing with social unrest across the country.

This new national pride combined with the high media profile of the Apollo program and its achievements inspired a generation to become excited about STEM (science, technology, engineering, and math). The data clearly shows higher and steadily growing levels of technical education in the years following. This generation would go on to harness the micro-electronic technologies developed during the Apollo program to wire, connect, and automate society in completely new ways—including people such as Steve Jobs, Steve Wozniak, Bill Gates, Jeff Bezos, and Elon Musk.

The Apollo program also forced people to view Earth differently. The famous Earthrise photo taken by the crew of Apollo 8 in 1968 forever changed our global perspective. For the first time, we saw our tiny, fragile planet sitting in the darkness of space, which focused our energies in new and unprecedented ways. This was later driven home by "The Blue Marble," another famous distant image of Earth taken four years later by the crew of Apollo 17. As Bill Anders, the Lunar Module Pilot for Apollo 8 who snapped the Earthrise photo, once said during an interview, "After all the training and studying we'd done as pilots and engineers to get to the Moon safely and get back ... what we really discovered was the planet Earth."

Fifty years have since passed, and the Apollo program no longer has the impact it once did. Surveys continue to show an eroding connection between Apollo and the public, especially with younger people. Members of Generation X and Millennials believe in growing numbers that the Moon landings were faked–from four percent 50 years ago as the landings were actually occurring to as high as 25 percent in some recent surveys. This view is exacerbated when current celebrities who have tremendous influence on young people also publicly adopt this view. Sadly, one of our crowning achievements is slowly turning into a distant memory, or even worse, an indictment against government and how far it will go to achieve some imagined sinister agenda.

Watching countless believers trying to convince nonbelievers that the Moon landings were real, it appears that we, as a group of space advocates, leaders, and enthusiasts, may be missing a critical point. Regardless of why a growing number of people don't believe, few dispute the amount of effort that went into the program—America's finest corporations and universities working tirelessly with NASA to research, design, and build the Saturn V (one of the largest, most powerful machines ever built), new communications systems, tools, test equipment, and other critical infrastructure and materials. That effort generated most of the positive outcomes of the Apollo program. However, it's also where the least amount of attention tends to be focused.

While most of the world only saw young, white male astronauts and members of Mission Control in the media, during the space race, the engineering effort of almost a half-million people of both genders and many races and cultures directly touched people's lives through the Apollo program's huge economic impact and generational inspiration. While humans walking on the Moon was a seminal moment in our history, the process of *striving to get there* may have been the most important aspect of the lunar landing program.

According to a 2018 study by the Pew Research Center, about 90 percent of those who are well informed about space news believe it is essential for the United States to continue to be a global leader in space exploration. That number drops significantly for those who haven't paid much attention. Similarly, 75 percent of those who are well-informed and attentive to space news believe that basic scientific research should be a top priority for NASA, versus a mere 31 percent for those who aren't. NASA has a public brand problem. With the beginning of a new age of space endeavor led by the likes of Elon Musk and Jeff Bezos, NASA must continue to stay relevant in the minds of today's youth through continued space-related research and the resulting positive economic impact. In other words, NASA must somehow directly touch people's lives.

Basic marketing theory suggests that for an organization to have an impact and cut through the noise, it must make an emotional connection with people in the simplest possible way. Public opinion polls have already shown how an emotional connection can impact the public view of NASA and space-related activity. Space historian Roger Launius has noted that movies such as "Apollo 13,""Armageddon,""Deep Impact," and "The Martian" appear to have buoyed interest in space exploration and shifted public sentiment in a positive way. In the same manner that movies can create an emotional connection, NASA and its supporters must adopt methods to more regularly connect with average people, not just those who are interested in space.


Pencil rendering of Mike Collins inside *Columbia*.
Credit: James Vaughan

People tend to gravitate towards the people, companies, and organizations they like—but what drives likability? It's the positive emotion and the experiences that come with it. Creating that emotion is often as simple as telling the story behind something, which creates a higher degree of authenticity and likability and allows people to more easily connect with the tale. One of the reasons SpaceX, Blue Origin, and Virgin Galactic tend to be more likable is because of the life stories of Elon Musk, Jeff Bezos, and Richard Branson. Their stories are frequently shared in the media, which provides people a point of connection when they hear about rocket launches, booster landings, and Tesla Roadsters orbiting Earth. As leaders, they also serve as the evangelists behind their efforts. This builds trust, creates loyalty, and generates advocacy.

For people to connect with a brand, it must have a genuine and personal story. They need to have positive experiences with the brand and know their voices are being heard. While NASA has made positive strides by making both the Kennedy and Johnson Space Center experiences more interactive and visually stimulating, they need to do much more to convey their story. They should put their visible failures (Apollo 1, *Challenger*, and *Columbia*) humbly front and center and in great detail explain what was learned. NASA should grow its outreach to include more K-12 institutions to create lasting positive experiences with as many children as possible. With every new product released to the market that uses a NASA-generated idea or innovation, the development, however small, must be added to the larger narrative so that people will see how NASA directly affects and improves their lives.

While there's obviously much more NASA could do, it is critical for all of us—space advocates, leaders, and enthusiasts—to become brand evangelists, working together to help the general public understand NASA's powerful impact on all of us. With the 50th anniversary of Apollo 11 upon us, now is the perfect time to share with everyone—whether they believe we actually landed on the Moon or not—how the process of planning and designing a trip to the Moon has made our world a better place.

Op-Ed: Caught Between the Moon AND A STEM CAREER

Burton Dicht
NSS Vice President for Membership

> The Apollo program encouraged countless young people to enter fields such as engineering, science and math. On this 50th anniversary, it's time to rekindle that passion.

As the celebration of the 50th anniversary of the first lunar landing of Apollo 11 unfolds, the influence and impact that the program had on people who were coming of age at the time should be remembered and embraced for the future.

I was 10 years old when Armstrong and Aldrin explored the lunar surface, and like people everywhere, was transfixed by the excitement and wonder of it all. The Apollo program led me to a career as an engineer in the aerospace industry. I was not alone; countless others were also influenced by the race to land humans on the Moon. Historians, social scientists, and essayists have explored and researched the impact that the Apollo program has had on science and engineering education and those pursuing such careers. Copious research supports the connection between Apollo and an influx of people into these career areas.

Eligar Sadeh, in his 1995 paper "Societal Impacts of the Apollo Program," notes that during the Apollo era there was a dramatic increase in the number of students in the United States pursuing advanced degrees in STEM-related fields, and that this number started dropping as the program's goals were met and NASA's budget declined in the late 1970s. By the time the Apollo generation grew up and settled into careers in the 1990s, they had become a new cohort of science and engineering professionals. In Andrew Chaikin's essay "Live from the Moon: The Societal Impact of Apollo," he recounts that countless scientists and engineers, and even a number of astronauts and flight controllers, were inspired to pursue their careers by the Apollo program.

Several well-known space entrepreneurs also trace their beginnings to the space race. In Christopher Riley's article in The Guardian, "Apollo 40 Years On: How the Moon Missions Changed the World Forever," he shares the Apollo-inspired stories of Bob Richards and Martin Sweeting. Richards, who co-founded the Students for the Exploration and Development of Space (SEDS), and is the CEO of Moon Express, described himself as "an orphan of Apollo." Sweeting, who founded the small satellite company SSTL, said, "Apollo started me on this whole pathway of getting involved in space."

Fast forward 50 years from that historic event and STEM education plays a prominent role in today's pre-university education, not only in the United States but in many countries around the world. NASA invests heavily in STEM programs. They are joined by technical professional societies

Above: NASA's equivalent of STEM outreach looked quite different in the 1960s. Here, biomedical engineer Judy Sullivan gains experience on a control console. Credit: NASA

Left: NASA is quite active in STEM education efforts. Astronaut Cady Coleman is seen here with a Japanese STEM outreach experiment that was taken outside the International Space Station, exposed to the vacuum of space, sealed and then returned to Earth as a STEM outreach tool—a "message in a bottle" as it was later called. Coleman is one of many NASA astronauts who has been intensely engaged in STEM efforts during and after her career in spaceflight. Credit: NASA

as well as a number of prominent technology companies, all for the purpose of inspiring the students of today to become the STEM professionals of tomorrow.

The concept of STEM education in the United States, although it was not called this at the time, has been around for many years. The Morrill Act of 1862, which established land grant universities, led to an eventual expansion of engineering programs. There were also major historical events that demonstrated the need for a technological workforce that pushed STEM education forward. In David W. White's "What Is STEM Education and Why is it Important?" he suggests that World War Two and the launch of Sputnik were two major driving forces. During the conflict, White states, "scientists, mathematicians, and engineers worked hand-in-hand with the military to produce innovative products to win the war and further STEM education."

Americans' early belief in the nation's technical prominence lasted until the Soviet Union launched Sputnik, the world's first artificial satellite, in 1957. The fact that the Soviets were first to orbit a satellite shocked many in the United States as the military and geopolitical implications were calculated. This led to the creation of NASA and vast new government investment in education and research that helped spur the creation of the vast STEM workforce that made the Apollo program possible.

During the 1990s, as the Apollo generation established themselves as STEM professionals, policymakers noted a disturbing trend in U.S. education: fewer students were choosing to study and enter such fields. The implications were serious, as technology drives the economy and is critical for security, health, commerce, and the protection of the environment. Officials at the National Science Foundation introduced the term STEM in 2001 and led efforts to introduce programs that continue to attract students to these fields.

STEM programs are prolific, penetrating many sectors including K-12 schools, universities, associations, and companies. This is not only a priority in the United States; many countries around the world have embraced these programs to help develop a technically literate talent pool that will address our global challenges. As an engineer who has worked his whole career to enhance STEM awareness and interest in students, I applaud and support these efforts. But as I think back to 50 years ago, it is clear to me I didn't need a STEM program—I had Apollo.

William Bainbridge sums up that influence best in his book "The Spaceflight Revolution," summarizing Apollo as "a grand attempt to reach beyond the world of mundane life and transcend the ordinary limits of human existence through accomplishments of the miraculous ... a story of engineers who tried to reach the heavens." For those of us in the Apollo generation, it was "an act of human ingenuity, Apollo made them giddy, intoxicated on admiration and inspiration."

We're now entering a renaissance in spaceflight development as space entrepreneurs are redefining rocket and spacecraft technologies. Let's use this 50th anniversary of Apollo 11 to introduce the wonders of Apollo to the students of today and inspire them to reach for the stars.

NSS Chapters

PROMOTING LUNAR SETTLEMENT

Claire Stephens McMurray

Learning about the Moon at the North Texas Chapter's 2018 Moon Day event. Credit: NSSNT

Public support is a precondition for any sustained American effort to settle humans on the Moon. Recently, many NSS chapter activities have focused on lunar settlement outreach and research.

PUBLIC AWARENESS

One very successful public awareness effort is the annual Moon Day event organized by the **NSS of North Texas** chapter in cooperation with the Greater Fort Worth Moon Society and the Frontiers of Flight Museum at Love Field in Dallas, Texas. It has drawn over 2,000 attendees and dozens of exhibitors, while local television and newspaper coverage reaches thousands more.

Local space groups and colleges provide speakers for a family-friendly Moon Academy and an adult-focused Lunar University. There are hands-on activities for people of all ages, with some aimed at helping children earn Boy and Girl Scout badges with STEM (science, technology, engineering, and math) activities. When the International Space Station orbit is favorable, AMSAT (the Radio Amateur Satellite Corporation) provides a live radio uplink that allows children to converse with the crew.

For years the **DC-L5 NSS chapter** has been videotaping spaced-related interviews. Several are now available on the YouTube channel "AroundSpaceTV10," including Dr. Kent Miller's 2018 "To the Moon, Uncle Sam" interview (show #141), with Ajay Kothari of Astrox Corporation. The India-born Kothari believes the next giant leap for the United States should be to build the first lunar settlement and invite other countries to build their own settlements nearby for mutual support.

Kothari says we should take this step before attempting a Mars mission because the Moon would be cheaper, and we should learn to solve the problems of living in its one-sixth gravity environment while only a few days away from Earth—valuable in case of an emergency. He feels that it should be possible to build a settlement for hundreds of people within four years, using several regolith-sheltered upper stages of the Falcon rocket family as habitats. The Falcon Heavy will allow architectures costing only $3,000 per pound ($6,000 per kilogram) for payloads delivered to the Moon. At that price, other countries may want to cooperate in the venture due to the public interest and prestige that might result.

HOW MIGHT LUNAR SETTLERS LIVE?

Although public interest is a precondition to lunar settlement, data and methodology are also needed. For over 30 years, Milwaukee's **Lunar Reclamation Society** chapter published the "Moon Miner's Manifesto," a newsletter about lunar settlement edited by Peter Kokh. Suppose you've decided to settle on the Moon and found a way to get there ... how will you survive the sub-zero, two-week lunar night or the scorching daytime temperatures? How can a lunar economy be created? The newsletter provided a plethora of practical answers, now fully contained in "A Pioneer's Guide to Living on the Moon," available on Amazon.

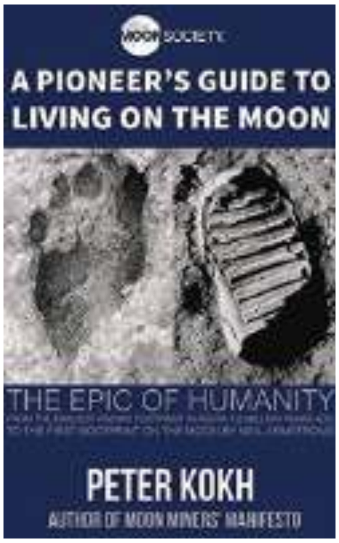
This material constituted some of the earliest original in-situ resource utilization (ISRU) research, and now includes much more. Kokh writes: "If everything around the pioneers has come from Earth, the Moon will remain cast as alien, as something from which we must keep ourselves safely apart. One way to break this psychological quarantine is to start making useful items or even merely decorative accessories from raw regolith."

Kokh's book suggests that lunar basalt would be useful for this–it is on the Moon, cheaper, lighter, and stronger than steel, and rust-proof. On Earth, cast slabs of basalt have been used in factory floors where abrasion resistance is important; such slabs have proven impervious to abrasion by Moon dust in tests. Basalt can even be spun into fiber; it is used in India for rebar in place of steel, and also for fabric soft enough to use for abrasion-resistant clothing.

WHERE COULD LUNAR SETTLERS LIVE?

Ideas for siting a lunar outpost differ; the Lunar Prospector probe's discovery of possible ice and a peak in near-permanent sunlight at Shackleton Crater near the lunar south pole has fired the imaginations of many. The **Sacramento L5 Society** chapter's Joe Bland and other members have done well-regarded work studying ways to make affordable solar-based power continuously available anywhere on the Moon. A wide variety of settlement locations could then be possible even without nuclear power. (See the summer 2018 issue of *Ad Astra* for more information),

Several years ago, the **Oregon L5 chapter** caught NASA's attention with its exploration of lava tubes as analogs for lunar shelters from radiation and micrometeorites. NASA contracts and subcontracts followed: "Site Characterization and Phase One



Cover of the paperback edition.
Credit: Amazon

Development Plan for the Oregon Moonbase," "Lunar Lava Tube Siting Options" (with Lockheed under NASA contract), and "Lunar Analog Site and Engineering Tests of a prototype Outpost Service and Construction Robot" (with Steve Kent of Rockwell International Space Systems). Data from lunar orbit has confirmed the existence of lunar lava tubes that are large enough to be useful as habitat shelters.

Earth-bound lava tubes have become a subject of considerable interest to space researchers. The **San Antonio Space Society** chapter is working on an LCATS—Lunar Caves Analog Test Sites—activity for secondary school students.

Back in November, 2018, **Tucson L5 Space Society** chapter members Alfred Anzaldua, David Dunlop, and Christian Meza coordinated with the Mexican National Space Agency (AEM) on an excursion to a lava tube in Mexico's Pinacate Biosphere National Reserve. Later, Anzaldua gave two space development lectures in Spanish to an astronomy class at the National Autonomous University of Mexico (UNAM) in Ensenada, Mexico. After these lectures many students expressed interest in space development, and the UNAM faculty agreed to organize a nation-wide robotics competition for first-year university students.

Anzaldua, now NSS Executive Vice President, has been working with UNAM and other Mexican universities to plan a national Mexican Moonbase Design and Robotics Competition during 2019 and 2020. Plans include a June 2019 orientation and workshop, an October design competition, and a February 2020 competition involving telerobotic rovers handling and transporting lunar analog materials.

Winners of this last competition will display and operate their rovers at the International Space Development Conference (ISDC®) 2020 in Dallas, Texas (hosted by the **NSS of North Texas** chapter). Lynne Zielinski, NSS Board of Directors member and VP of Public Affairs, is also involved. NSS Governor Henk Rogers of the Hawai'i Space Exploration Analog and Simulation (HI-SEAS) habitat may host one or more Mexican teams at the Lunar (formerly Mars) Base Analog Station in Hawaii after ISDC 2020.

Other NSS chapters are also involved with lunar settlement planning, outreach, and research. The list continues to grow. For more information, visit space.nss.org/nss-chapters-directory and check chapter websites.

LOCAL AND SPECIAL INTEREST CHAPTERS

Learn what local NSS chapters are doing at:
space.nss.org/community-chapters/

Get the latest chapter contact information updates at:
space.nss.org/nss-chapters-directory/

Please send any changes to the Chapters List Administrator at:
ChapList_Admin_N5@nss.org.

CHAPTER COORDINATORS

Vice-President for Chapters
Larry Ahearn
LDAhearn@aol.com
773-373-0349

Chapters Committee Chair
David Stuart
dstuart@prodigy.net
206-241-6165

Chapters Support Liaison at NSS HQ
Jill Jackson
nsshq@nss.org
202-429-1600

Chapters Resources Coordinator
Larry Ahearn
LDAhearn@aol.com
773-373-0349

Chapters Internet Coordinator
Ronnie Lajoie
CIC_J7@chapters.nss.org
256-509-3833

Chapters Assembly Chair
Joseph Bland
spaceportorbust@me.com
916-429-6252

UNITED STATES CHAPTERS

U.S. Chapters Coordinator
Bennett Rutledge
rutledges@chapters.nss.org
720-641-7987

U.S. NORTHEAST DISTRICT CHAPTERS

Northeast District Chapters Coordinator
Dennis Pearson
dpearson@enter.net
610-434-1229

DC — DC-L5
P.O. Box 3955
Merrifield, VA 22116
Contact: Donnie Lowther
DC-L5@AroundSpace.com
703-354-2665
AroundSpace.com

NJ — NSS Space and Astronomy Society of NW Jersey
P.O. Box 270, Oxford
NJ 07863-0270
Contact: Karl J. Hricko
hrickokj@embarqmail.com
908-227-3852
facebook.com/NSSJERSEY

OH — Cuyahoga Valley Space Society
5819 W. 29th Street, Apr 103
Parma, OH 44134-2965
Contact: George Cooper
geocooper3@aol.com
440-558-2544
sites.google.com/site/cuyahogavalleyspacesociety

PA — NSS Philadelphia Area Space Alliance
928 Clinton Street, #6
Philadelphia, PA 19107
Contact: Earl Bennett
earlisat@verizon.net
856-261-8032
philadelphia.nss.org

U.S. SOUTHEAST DISTRICT CHAPTERS

Southeast District Chapters Coordinator
Fred Becker
mach25@comcast.net
321-271-9064

AL — Huntsville Alabama L5 Society
P.O. Box 22413
Huntsville, AL 35814
Contact: Greg Allison
info@HAL5.org
256-859-5538
HAL5.org

FL — Florida Space Development Council
P.O. Box 510136
Melbourne Beach, FL 32951
Contact: Goddard "Gabriel" Rothblatt
fsdcnss@gmail.com
321-209-4223
fsdc.space

KY — NSS Louisville Space Society
1019 Lampton Street
Louisville, KY 40204
Contact: Gregory J. Hart
louisvillespacesociety@protonmail.com
502-500-9485
facebook.com/louisvillespacesociety

TN — Middle Tennessee Space Society
508 Beechgrove Way
Burns, TN 37029
Contact: Chuck Schlemm
cschlemm@comcast.net
615-969-4523
facebook.com/Middle-Tennessee-Space-Society-1457043781189997

U.S. NORTH CENTRAL DISTRICT CHAPTERS

North Central District Chapters Coordinator
Larry Ahearn
LDAhearn@aol.com
773-373-0349

IL — NSS Chicago Society for Space Studies
700 Cape Lane
Schaumburg, IL 60193
Contact: Jim Plaxco
JimPlaxco@chicagospace.org
847-923-7122
chicagospace.org

IL — NSS Illinois North Shore
1364 Edgewood Lane
Winnetka, IL 60093
Contact: Jeffrey G. Liss
JGLJGL@aol.com
847-446-8343

MN — Minnesota Space Frontier Society
8625 W. River Road
Brooklyn Park, MN 55444
Contact: Scott Shjefte
Quester@yahoo.com
763-560-7200
MNSFS.org

WI — Milwaukee Lunar Reclamation Society
P.O. Box 2102
Milwaukee, WI 53201
Contact: Peter Kokh
KokhMMM@aol.com
414-210-2118
moonsociety.org/chapters/milwaukee

WI — Sheboygan Space Society
728 Center Street, Kiel, WI 53042
Contact: Wilbert G. Foerster
astrowill@frontier.com
920-894-1344
sheboyganspacesociety.org

U.S. SOUTH CENTRAL DISTRICT CHAPTERS

South Central District Chapters Coordinator
Sean Freeman
nss-sc-district@warmpuppy.net
214-493-9757

MO — NSS St. Louis Space Frontier
2632 Roseland Terrace
St. Louis, MO 63143
Contact: Christine Nobbe
StLSpaceFrontier@gmail.com
StLouisSpaceFrontier.org

OK — Oklahoma Space Alliance NSS
P.O. Box 1003, Norman, OK 73070
Contact: Clifford McMurray
cliffmcmurray@hotmail.com
405-329-4326
osa.nss.org

TX — Clear Lake Area NSS
8327 Lanham Lane
Houston, TX 77075-2658
Contact: Eric H. Bowen
info@nss-houston-moon.org
713-991-3575
nss-houston-moon.org

TX — National Space Society of North Texas
P.O. Box 541501, Dallas, TX 75354
Contact: Ken Ruffin
nssofnt@yahoo.com
972-383-2723
nssofnt.org

TX — NSS Austin Space Frontier Society
12717 Bullick Hollow Road
Austin, TX 78726-5204
Contact: John Strickland, Jr.
jkstrickl@sbcglobal.net
512-258-8998
austinspacefrontier.org

TX — NSS North Houston
9237 Swansea Bay Drive
Spring, TX 77379
Contact: Nathan Price
nathan.price@gmail.com
832-620-6385
NorthHoustonSpace.org

TX — San Antonio Space Society
609 Ridge View Drive
San Antonio, TX 78253
Contact: Joe B. Redfield
credfield@stmarytx.com
210-679-7625

U.S. CALIFORNIA DISTRICT CHAPTERS

California District Chapters Coordinator
James Spellman, Jr.
wspaceport@aol.com
760-379-2503

CA — NSS San Francisco Chapter
4893 Deep Creek Rd
Fremont, CA 94555
Contact: Dr. Wun C. Chiou, Sr.
wchiou@gmail.com
415-827-4411
NSS.SPACE/SanFrancisco

CA — OASIS
P.O. Box 1231
Redondo Beach, CA 90278
Contact: Seth Potter
oasis@oasis-nss.org
310-245-2592
oasis-nss.org

CA — Sacramento L5 Society
7482 Greenhaven Drive
Sacramento, CA 95831
Contact: Joseph Bland
spaceportorbust@me.com
916-429-6252
SacL5.org

U.S. INDEPENDENT DISTRICT CHAPTERS

Independent District Chapters Coordinator
Bennett Rutledge
rutledges@chapters.nss.org
720-641-7987

AZ — Phoenix Chapter of The NSS
P.O. Box 917
Tempe, AZ 85280
Contact: Phyllis Redhair
Phyllis.Redhair2012@gmail.com
602-737-5185
nssphoenix.wordpress.com

AZ — Tucson L5 Space Society
7511 E. Lakeside Drive
Tucson, AZ 85730
Contact: Christian Meza
tucsonspace@gmail.com
520-850-2252
l5space.org

CO — Denver Space Society
1 Cherry Hills Farm Drive
Englewood, CO 80113
Contact: James W. Barnard
trailrdr@ecentral.com
303-791-6114
denverspacesociety.blogspot.com

OR — Oregon L5 Society, Inc.
P.O. Box 86
Oregon City, OR 97045
Contact: Thomas Billings
info@OregonL5.org
360-314-4309
OregonL5.org

UT — Utah Space Association
378 I Street
Salt Lake City, UT 84103
Contact: J. David Baxter
baxman2@q.com
801-359-0251
utahspace.org

WA — NSS Seattle
14618 21st Avenue SW
Burien, WA 98166-1606
Contact: David Stuart
dstuart@prodigy.net
206-241-6165
seattle.nss.org

INTERNATIONAL CHAPTERS

International Chapters Coordinator
Claire McMurray
cliffclaire@hotmail.com
405-329-4326

Australia

National Space Society of Australia
GPO Box 7048
Sydney, NSW, 2001
Contact: Wayne Short
nssa@nssa.com.au
61-2-9150-4553
nssa.com.au

Newcastle Space Frontier Society
P.O. Box 1150
Newcastle, NSW, 2300
Contact: Jack Dwyer
nsfs@nssa.com.au
61-2-4963-5037
nssa.com.au/nsfs

Sydney Space Frontier Society
GPO Box 7048
Sydney, NSW, 2001
Contact: Wayne Short
ssfs@nssa.com.au
61-2-9150-4553

Canada

Calgary Space Frontier Society
218-200 Lincoln Way
Calgary, AB, T3E 7G7
Contact: Paul Swift
pswift@shaw.ca
403-686-7430
members.shaw.ca/pswift

Germany

Deutsche Raumfahrtgesellschaft e.V. German Space Society (GSS)
Rinkerodeweg 21, 48163 Muenster
Contact: Michael Stennecken
Info@DeutscheRaumfahrt.de
49-251-3944863
deutscheraumfahrt.de

Greece

Greek NewSpace Society
Rodon 6
Zografou, 15772
Contact: George Profitiliotis
greeknewspacesociety@gmail.com
30 6973839004
greek.nss.org

India

New Delhi Space Society
B-30, First Floor
Lajpat Nagar4-3
New Delhi, Delhi, 110 076
Contact: Saksham Arora
nssnewdelhispacesociety@gmail.com
91-7042071881
facebook.com/NewDelhiSpaceSociety

Dr. A.P.J. Abdul Kalam Initiatives
Office 107
Near kashivishweshwar Temple, Kasaba
Pune, Maharashtra, 413 102
Contact: Avishek Ghosh
contact@drkalaminitiatives.org
1-650-305-5811

NSS (USA) - Nashik India Chapter
35, Panchavati Housing Society, Vijaynagar, New Adgaon Naka
Nashik, Maharashtra, 422 003
Contact: Avinash Shirode
avishirode@gmail.com
91-942-2245300

Japan

NSS Japan Chapter
2-23-17 Komachi
Kamakura, Kanagawa, 248-0006
Contact: Taichi Yamazaki
taichi.yamazaki@astrax-by-iss.com
81-90-2644-3458
astrax.space

South Africa

Cape Town Space Society
Unit 1, 8 Rainbow Circle
Montagu Gardens
Cape Town, 7447
Contact: Hildreth (Hal) Walker, Jr.
hwaslerjr@aol.com
27 83 6420414
capetownspacesociety.org.za

SPECIAL INTEREST CHAPTERS

Space Nursing Society
3053 Rancho Vista Blvd, #H377
Palmdale, CA 93551
Contact: Linda Plush
lplushsn@ix.netcom.com
661-949-6780
spacenursingsociety.org
Interest: Space Nursing

JOIN A CHAPTER OR START A NEW ONE

If you support the exploration and development of space and the creation of a spacefaring civilization, joining the National Space Society (NSS) is a good first step. But what if you want to do more?

If you want to meet others of like mind, if you want to explore how your special interests and abilities fit into the larger picture, If you want to share your enthusiasm, if you want to engage in research or teach others about space, then you should join an NSS Chapter. It's easy!

Your first step is to see if there is a chapter that meets your needs already. Chapter contact listings are in every issue of "Ad Astra" and online at **chapters.nss.org/a/lists**. Then contact the local leaders or check their Chapter websites for upcoming events and activities near you.

Local chapters also often concentrate in special areas (e.g., rocketry, education, original peer-reviewed research on space settlement, etc.) and will generally welcome distant members who share their particular interests.

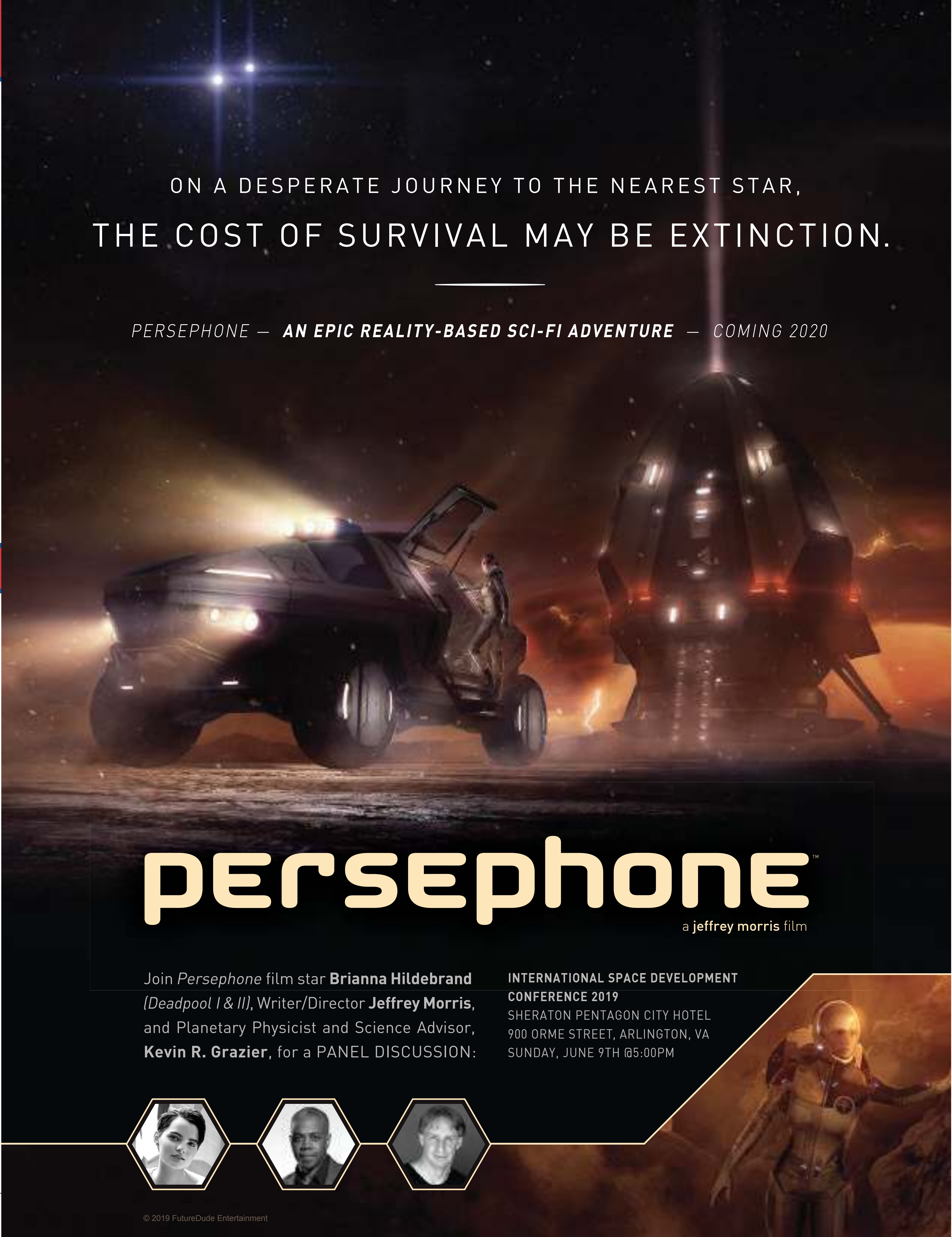
If there are no existing chapters that meet your needs, you may want to form a new one. Instructions are available on the NSS Web site at: chapters.nss.org. You may also contact Chapters Resources Coordinator Larry Ahearn to get a NSS Chapter Starter Kit emailed or mailed to you. Chapters in good standing with the NSS have access to assistance and resources from both NSS national and other nearby chapters. Resources from both NSS national and other nearby chapters. Resources include promotional materials, educational materials, and membership recruitment rebates. See **chapters.nss.org/a/resources** for more details.

BUZZ ALDRIN COUNCIL [LIFETIME OF $5000+]

Steve T. Adamczyk
John Adams
P. Alpaugh
Edward Apke
Janet Asimov
Daniel Babcock
Jack Bader
Blandy Boocock
Amy Bouska
Greg Brand
Randall Buss
Christopher Butcher
Paul Canolesio
John Clancy
Bruce Clark
Michael Cronin
Hoyt Davidson
Robert Dettmer
Donald Disraeli
Stephen Donaldson
Richard Dowling
Hugh Downs
Mike Dudley
Bob Everett
Ramon Eves
Alfred Ewell
Mark Ferrari
Gregg Foote
Marc Foulkrod
Richard Garriott de Cayeux
Frederick Graboske
David W. Gray
Jim Haislip Jr.
David Hamlin
David Hampton
Mark Herrup
Daryl Hester
J. Hirche
Hugh Hotson Jr.
John Irwin
Neil H. Jacoby, Jr.
Carol Johnson
Edwin Jones, Ph.D.
David and H.B. Kaplan
William Kelley
Dean Kennedy
David Korpi
Ronnie Lajoie
J. Michael Lekson
Charles Lenzmeier
Michael Livanos
Matthew Marchese
Pat Martin
Karen Mermel
C. Rick Miller
Mary Morss
Candace Pankanin
John Melvin Pinto
John Pritchard
Pete Ricketts
Bina Rothblatt
Gabriel Rothblatt
Martine Rothblatt
Greg Rucker
Edwin Sahakian
Tim Seeley
David Shulan
Frederick V. Simms
Randall Skinner
Dale L Skran Jr
Shirley M. Sontheimer
Gregory Stanley
John Swanson
Eric Tilenius
Pat Tomasko
Michael Tomkins
Patrick Trani
Raymond Visneski
Barry Watson
Doug West
George Whitesides
Jay Wittner
Cynthia Yarborough

MAJOR DONORS [$350+ IN PAST 12 MONTHS]

Robert Adolfsen
P. Alpaugh
Jeff P. Anderson
Kennith Armour
Mark Aton
Daniel Babcock
Jack Bader
Chantelle Baier
Kevin Baines
Christine Becker
Richard K. Beckwith
Carolyn Beltz
Cory Boyle
Christopher Bradley
Greg Brand
Greg & Dawn Brown
George and Sandy Bush
Randall Buss
Reb Butler
Tom Caldwell
Stewart Davey
Hoyt Davidson
Robert Dettmer
Burton Dicht
Stanley F. Dole
Stephen Donaldson
Geoffrey A. Dorn
Rick Dotterer
Richard Dowling
Bruce Egloff
David Ehrlich
Mark Fernandez
Marc Foulkrod
Thomas Furlong
Charles Gould
Charles Green
Vincent Greene
David Hamlin
David Hampton
Christopher Hancock
John L. Hank
Eric Hayes
Thomas B. Hayward
Mark Herrup
Claudia Hester
J. Hirche
John Hrivnak
Mijan Huq
Neil L. Inglis
Jeffrey A. Jaschinski
Carol Johnson
Edwin Jones, Ph.D.
Richard Kacik
Phillip Kvamme
Louis M. Kwong, M.D.
Ronnie Lajoie
J. Michael Lekson
Charles Lenzmeier
Fred C. Link
Thomas M. Lutgens
Julie Magilen
Douglas C. Mallory
Matthew Marchese
Jeffrey Mark
Graham McIntosh
C. Rick Miller
David Miller
M. Michael Miller
Mary Morss
Kenneth Morton
Mark Mosch
Jason Orr
Jerald V. Parker
Daniel Pederson
Bruce Pittman
John Pritchard
Eric & Angela Richey
Henk Rogers
Michael Rosen
Bina Rothblatt
Gabriel Rothblatt
Martine Rothblatt
Kenneth Ruffin
Robert Santini
Peggy L. Schultz
Tim Seeley
Geoffrey Shiflett
Frederick V. Simms
James Sloan
Shirley M. Sontheimer
George Sowers
Cyrus Spurlino
Lawrence Squeri
Gregory Stanley
William Sticklen
Russell Stowe
Scott Strobel
Paul Swan
John Swanson
Steven Tague
Alethea Taylor
Michael Tomkins
Javier Urzay
Edward Veal
Doug West
Peter Wilhelm
Fillmore Wood
Brian Yanagitani
Greg Young


ON A DESPERATE JOURNEY TO THE NEAREST STAR,
THE COST OF SURVIVAL MAY BE EXTINCTION.
PERSEPHONE — AN EPIC REALITY-BASED SCI-FI ADVENTURE — COMING 2020
persephone™
a jeffrey morris film
Join Persephone film star Brianna Hildebrand (Deadpool I & II), Writer/Director Jeffrey Morris, and Planetary Physicist and Science Advisor, Kevin R. Grazier, for a PANEL DISCUSSION:
INTERNATIONAL SPACE DEVELOPMENT CONFERENCE 2019
SHERATON PENTAGON CITY HOTEL
900 ORME STREET, ARLINGTON, VA
SUNDAY, JUNE 9TH @5:00PM
© 2019 FutureDude Entertainment

CONTINUING THE JOURNEY

ISDC® 2020

International Space Development Conference®

May 28-31, 2020

Embassy Suites by Hilton Dallas-Frisco Hotel & Convention Center

ISDC2020.nss.org

National Space Society