ad Astra

the magazine of the National Space Society

DEDICATED TO THE CREATION OF A SPACEFARING CIVILIZATION

ARE SPACE SETTLEMENTS
EASIER THAN WE THINK?

A SPACEWALKING FIRST
AN ALL-FEMALE CREW

BUZZ ALDRIN AT 90
AN EXCLUSIVE INTERVIEW

2020-1 || space.nss.org

NSS
National Space Society

EXCLUSIVE OFFER FOR NSS MEMBERS

NO Balance Transfer Fees, **NO** Annual Fee, **NO** Foreign Transaction Fees

Apply today at **nasafcu.com/NSS**
or call **1-888-NASA-FCU (627-2328)**

NASA FEDERAL CREDIT UNION
SMART. NASA SMART.

*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 (11.15%-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 (11.15%-17.99%). Cash Advance APR (13.15%-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 January 24, 2018 and are subject to change. Eligibility and Membership in NASA FCU required. All offers subject to credit approval. This credit union is federally insured by NCUA.

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."

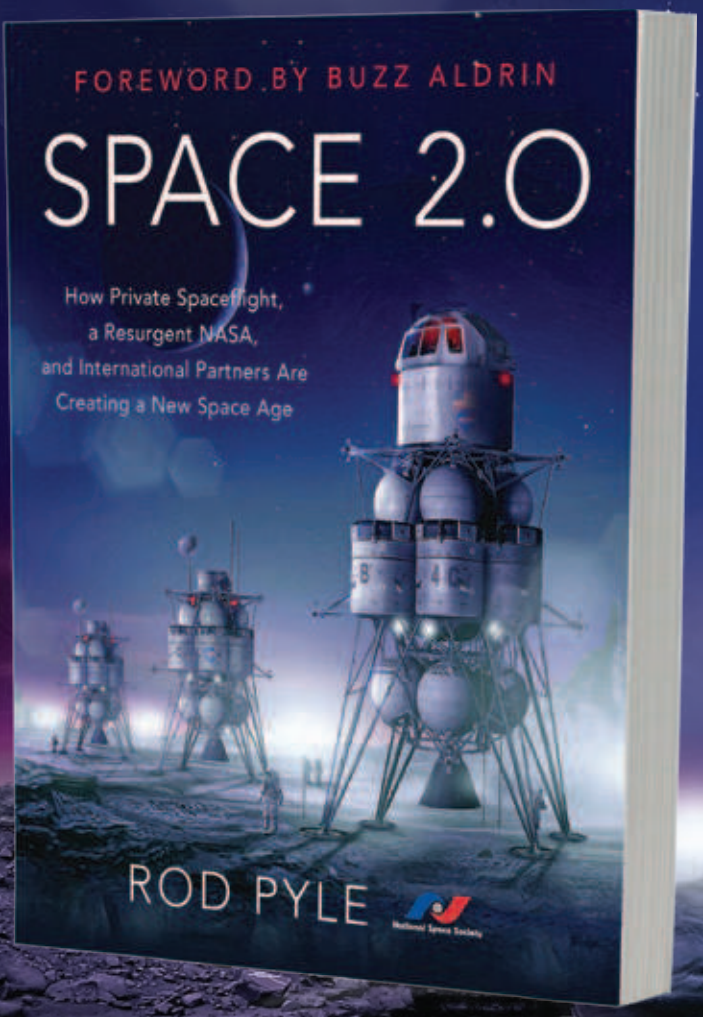
—GEOFFREY NOTKIN, member of the board of governors for the National Space Society and Emmy Award-winning host of *Meteorite Men* and *STEM Journals*

"...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

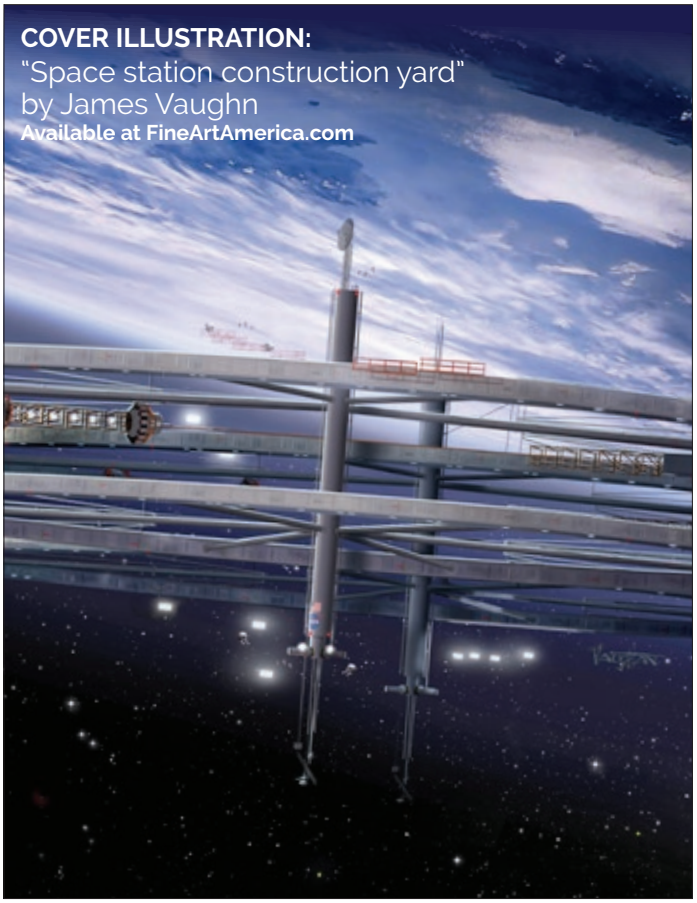
"Optimistic, but not over-the-top so. Comprehensive, from accurate history to clearly outlined future prospects. Sensitive to the emerging realities of the global space enterprise. Well-written and nicely illustrated. In *Space 2.0*, Rod Pyle has given us an extremely useful overview of what he calls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



COVER ILLUSTRATION:
"Space station construction yard"
by James Vaughn
Available at FineArtAmerica.com

Contributors + Columnists

Winter 2020
Volume 32 · Issue 1

Alfred Anzaldúa
Nancy Atkinson
David Brandt-Erichsen
Francis French
John Gould
Mark Hopkins
John F. Kross
Claire Stephens McMurray
Anthony Paustian
Rod Pyle
Dale Skran
Melissa Silva
Aida Wofford

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

DESIGN CONSULTANT
Geoffrey Notkin

PRINTING + MAILING
Publication Printers
Denver, CO

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

Rhonda Stevenson
720.327.9051
rhonda.stevenson@nss.org

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

Ad Astra, ISSN 1041-102X, is published quarterly by the National Space Society at 11130 Sunrise Valley Dr., Suite 350, Reston, VA 20191.

For questions about membership, please call 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 Drive
Suite 350, Reston, VA 20191.

SPACE TREK®

SPACE CAMP
at Kennedy Space Center
with SPACE TREK®

3 and 5 days Space Trek camps

MISSION ROBOTICS

Drive your own Martian rover

Experience Mars surface exploration like a NASA scientist and conduct robotics missions on our state-of-the-art simulated Martian surface.

ROCKETRY

Rocket science for everyone

Learn all about the science behind rocketry as you construct and launch water rockets like a real NASA team sending astronaut crews into space.

NEAR SPACE INVESTIGATION

Reach out to the edge of space

Build experiments and flight hardware to launch a scientific payload in the atmosphere on a High Altitude Balloon ascending to 100,000 ft

All programs include:

Tour of exhibits at KSC visitor complex | Visit launch pads | Shuttle launch experience | Guided tour of Space Shuttle Atlantis | Enjoy NASA Astronauts' inspirational stories over lunch | Watch space IMAX movies | Shop at the biggest Space shop

Order **High Altitude Balloon** and **Rocketry kits** for your **school**

You can now conduct Space Trek programs on your campus. Order NSI and Rocketry kits, and our team of highly experienced instructors will assist you to plan and conduct hands-on STEM classes to enhance your curriculum. Call us now to find out more!

Space Trek Camps start at $382.95

YOUR NEXT **SPACE** ADVENTURE **AWAITS!**

For **registration** and **details:**

camp@spacetrek.com +1 321 210-8472

spacetrek.com

Follow Us:

Contents

FEATURES

DEPARTMENTS

COMMS

COUNTDOWN

SETTLEMENT

NSS LOUNGE

National Space Society

The Gerard O'Neill Voyagers Circle

We are extremely grateful to our Circle and hope you will join this special group, too. Circle members have donated $500 and pledged to set aside part of their estates for NSS or donated at least $5000 to help bring about a future with millions of people living and working in space. Circle members include:

Chantelle Baier
Christine Becker
Sherry Bell
Don Boudeman
Bob Brodbeck
Randall Buss
Teresa Conner
Joshua Conner
Hoyt Davidson
Frances Dellutri
Burt Dicht
Richard Dowling
Art Dula
Lorna Jean Edmonds
Anita Gale
Alice M. Hoffman
Mark Hopkins
Paul Jaffe
Karlton D. Johnson
Edwin Jones
Ronnie Lajoie
Scott Maclaren
Geoffrey Notkin
Dave Pierce
Bruce Pittman
Timothy Raupp
Carol Redfield
Joe Redfield
Bina Rothblatt
Gabriel Rothblatt
Martine Rothblatt
Herman Rubin
Tanya Sienko
Dale Skran
John K. Strickland, Jr.
Stephen Trimberger
Miriam Winder

If you plan to include, or already have included, the NSS in your estate plans, please join this wonderful and generous group of individuals. Please visit our website, estate planning guide and benefits calculator at **https://plannedgiving.nss.org,** e-mail us at **planned-giving@nss.org**, and/or call Mr. Todd Kapp, our Benefits Manager, at **(262) 914-2378**.

SALUTING TWO VISIONARIES
OF THE SPACE AGE

Rod Pyle, *Ad Astra* Editor-in-Chief

When one interviews Buzz Aldrin, it's rarely a casual affair. He's affable enough, and quite engaging, but at 90 years of age he's still thinking intently about space and how to get us out there further. So you'd better bring your 'A' game to the discussion, or quickly get left behind.

For this issue of *Ad Astra*, I've combined a number of interviews I conducted with Aldrin over the years to celebrate his 90th birthday. The first of these interviews was in 2005 for an Apollo 11 documentary I was producing for The History Channel, and the most recent just a few weeks ago.

What becomes clear when speaking with Aldrin is that he not only has much to say, but still has much left to do. He feels that the work we started in the first Space Age is largely incomplete, and that we need to move quickly and boldly into the new era of spaceflight—let's call it space 2.0. He sees this as much different than the Space Age that propelled Neil Armstrong and himself to the lunar surface. This new space age is about lower cost access to space, reusability, frequent transits to nearby worlds, and international cooperation. He is not shy about advocating cooperation with China.

I need not remind readers that Aldrin has been a key player on the NSS's Board of Governors since the 1980s, and has given his time generously and tirelessly to our organization. Beyond that, he is one of the few astronauts from NASA's first decade that has pushed continuously—and vocally—for stepping up our commitment to human spaceflight since he returned to Earth in 1969.

Ad Astra also wishes to salute D.C. Fontana, famed writer of *Star Trek* and other science fiction shows, who passed away on December 2nd. Fontana, full name Dorothy Catherine Fontana, worked for Gene Roddenberry as a story editor on the original *Star Trek*, and was so skilled at her job that he soon had her writing scripts. She used the non-gender-specific moniker "D.C. Fontana" because there were few women science fiction writers in the 1960s, and almost none writing for television.

After the series was cancelled, Fontana worked on a number of other shows, including Roddenberry's *Genesis II* pilot, the animated *Star Trek* series, episodes of *The Six Million Dollar Man*, and later *Star Trek: The Next Generation* and *Star Trek: Deep Space Nine*. Over the years she received a number of awards for her writing as well as recognition from her fans, who found her *Star Trek* storylines to be some of the most engaging of the long-running franchise.

Ad Astra, Dorothy Fontana. You were a visionary in a field full of brilliant creators.

CELEBRATE SPACEFLIGHT AND THE APOLLO MOON PROGRAM 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 and the future of human spaceflight to Mars and beyond. Join Rod Pyle, author, journalist, and Editor-In-Chief of Ad Astra magazine, as he hosts Apollo astronauts and leaders from Mission Control for a stunning historical experience you'll remember for another 50 years. Pilot a VR spacecraft to the planets. Relive our first journeys to the Moon in a behind-the-scenes tour of the Kennedy Space Center. Sip cocktails crafted by a robot at Bionic Bar® while exploring seven floating neighborhoods packed with amazing, innovative and first-at-sea experiences. Savor reimagined rustic Italian cuisine by celebrity chef Jamie Oliver. Hand jive along to the hit Broadway musical Grease. 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 WESTERN CARIBBEAN & PERFECT DAY

Departing March 21, 2021 | Sailing from Port Canaveral (Orlando), Florida

Cozumel, Mexico • Roatan, Honduras • Costa Maya, Mexico • Perfect Day at CocoCay, The Bahamas

For more information about this cruise please call 949-727-1211.

BEST CRUISE LINE 17 YEARS RUNNING
OVERALL AND IN THE CARIBBEAN
Travel Weekly Readers' Choice Awards

CONNECTION to CRUISE
CRUISES · VACATIONS · EXTRAORDINARY SERVICE

RoyalCaribbean INTERNATIONAL

*Features vary by ship. All itineraries are subject to change without notice. ©2020 Royal Caribbean Cruises Ltd. Ships' registry: The Bahamas. 19067798 • 5/13/2019

SPACE-BASED ASTRONOMY **IS OUR FUTURE**

Dale Skran, Chair of the Executive Committee of the National Space Society

Recently, there has been considerable anxiety expressed by both the general public and professional astronomers as we realize that mega-constellations of broadband satellites are becoming a reality in our skies. Some astronomers were surprised to see a "conga line" of SpaceX Starlink satellites crossing the night sky early during their deployment, and radio astronomers are concerned about electromagnetic emissions from these fleets of orbital radio sources. Amateur astronomers also fear that they lack the tools to subtract the interference caused by increasingly numerous satellites.

The National Space Society has long supported both professional and amateur astronomy. Astronomy is the root that leads to space development and settlement. Many astronauts, engineers, and other space professionals first got excited about space while looking at the night sky with a small telescope. The NSS supports efforts by companies to decrease the visibility of their satellites and avoid interference with radio astronomy. Additionally, the NSS encourages professional astronomers to make publically available the image processing software needed to deal with satellite-caused visual artifacts.

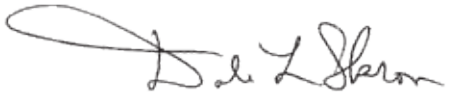
However, it is inevitable that as the development and eventual settlement of space expands, the night sky will be visibly altered beyond what ground telescopes can compensate for. In time, when solar power satellites, orbital hotels, fuel depots, and zero-gravity factories are added to the mega-constellations in orbit, the night sky will be covered with a "glitter band" of human constructs.

This point may not be reached for many decades, but to the extent humanity successfully extends its reach toward the vast resources of space, it will come. Space advocates need to own the consequences of this, and one of the most significant will be that ground-based astronomy will become increasingly difficult. Fortunately, the true golden age of astronomy is in the future, when space based telescopes eclipse those on the ground. The technology that enables the "glitter band" to surround Earth will also allow us to construct an array of in-space instruments exceeding in capability anything possible on the ground.

Currently, ultraviolet, infrared, x-ray, and gamma-ray astronomy is only possible in space, since these wavelengths do not penetrate Earth's atmosphere very well. The Hubble Space Telescope demonstrated that a large telescope in space could be operated and repaired over many years. In order to bring about the future of space-based astronomy, the NSS calls for the following:

- The continued support by the U.S. government of large, cutting-edge telescopes in space, with an emphasis on in-space assembly, repairability, and upgradability,
- The development of mass-produced, smaller, yet highly capable space-based telescopes for optical wavelengths to replace ground-based instruments,
- The full exploitation of space to create large interferometers at various wavelengths,
- The construction—by an international consortium—of a radio telescope on the far side of the Moon, where it will be shielded from Earthly radio emissions,
- And the launch of small (cubesat-sized), networked telescopes that amateur astronomers can use to scan the skies.

If we take these steps now, we will reap the scientific benefits of a new generation of more capable telescopes while preparing for a future in which Earth-based astronomy becomes increasingly difficult. As our usage of space resources grows, the cost of space-based telescopes will decline and eventually become more cost-effective. Additionally, space-based telescopes will not disrupt areas of natural beauty on Earth, or conflict with sacred sites such as Mauna Kea in Hawaii. The NSS urges that these programs be funded so astronomers can transition from Earth-based to space-based telescopes with a minimum of career disruption. Although this may seem counterintuitive, a vigorous and well-funded program of space-based astronomy is a critical foundation of future space development and settlement.



COUNTDOWN

View of SpaceX's Starship Mk. 1 after the top of a pressurized cryogenic tank blew off during a test.
Credit: K.C. Lee

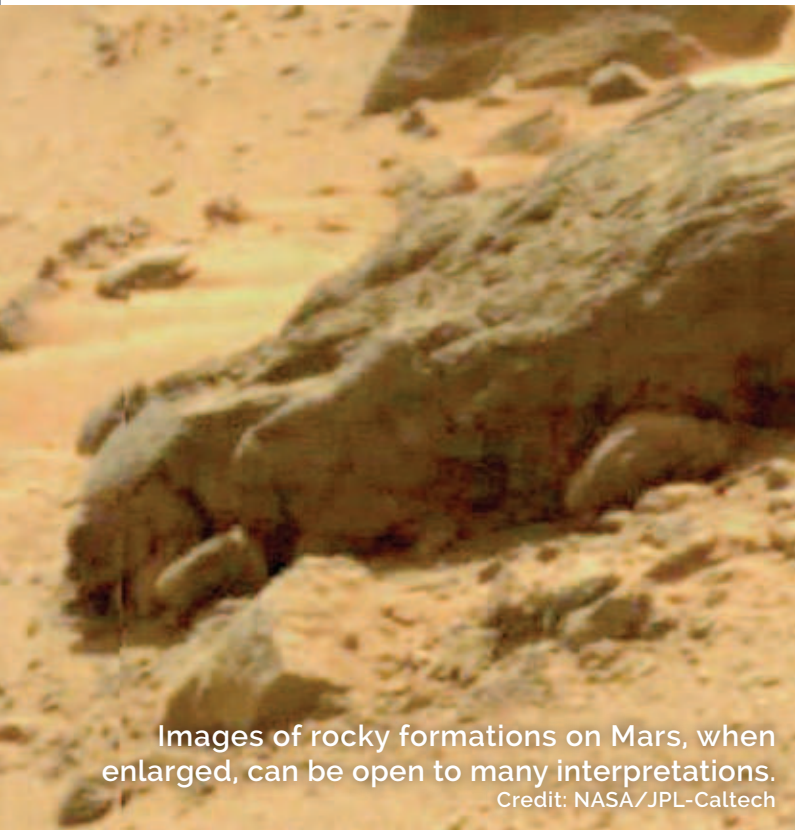
5 POP-TOP

During a pressurization test of SpaceX's gleaming new Starship Mark 1 test item on November 20, the prototype blew the top of its fuel tank high into the sky. Were this a more traditional company the test failure might have been considered a major setback, but SpaceX characterized this as a part of their iterative "fail fast, fail forward" philosophy. As the company said soon after the anomaly, "The purpose of today's test was to pressurize systems to the max, so the outcome was not completely unexpected . . . There were no injuries, nor is this a serious setback." They further added, "The decision had already been made to not fly this test article and the team is focused on the Mark 3 builds, which are designed for orbit."

4 LOOK OUT BELOW

A launch of a Long March 3 rocket in China on November 22 successfully delivered its payload to orbit, but with severe consequences on the ground. A spent stage from the booster came crashing back to Earth, destroying a home in a rural area downrange from the launch complex. Worse still, the stage still had highly toxic hypergolic fuel aboard, but no injuries have yet been reported. This is not the first time a booster stage has crashed downrange in China, and is one reason NASA and other space agencies generally build their launch complexes on the coasts (so that any falling debris will land harmlessly in the ocean).

Impact site of a Long March 3 upper stage that crashed in a rural area shortly after launch.
Credit: Y. Loo



Images of rocky formations on Mars, when enlarged, can be open to many interpretations.
Credit: NASA/JPL-Caltech

3 BUGS ON MARS?

Professor emeritus William Romoser of Ohio University recently published a paper with a bold claim: he's found insects on Mars. The assertion was made after Romoser studied reams of images from NASA's Mars rovers. In a press statement, he said, "There has been and still is life on Mars," adding that he could clearly make out bug-like features from the photographs. The pushback has been rapid, with many pointing out that the images are low-resolution when magnified to this extent, and therefore open to interpretation. A professor at Oregon State University further pointed out that people, even scientists, often see what they want to see and what is familiar in their area of study. It's called pareidolia, and occurs when people see familiar patterns in random images—in this case, bugs. Since Romoser studies insect-borne viruses, this may make more sense than cockroaches living on the Red Planet.

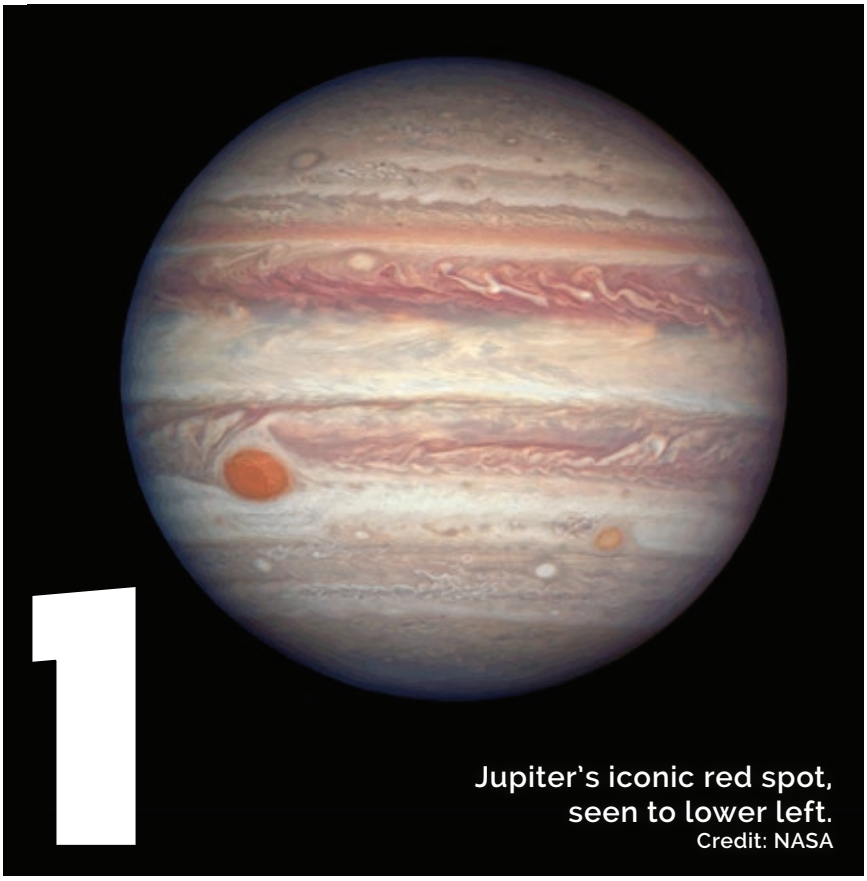
A visualization of India's Vikram lander during terminal descent, had things gone according to plan.
Credit: ISRO

2 HARD LUCK FOR VIKRAM

The Indian government recently released a report about its failed Vikram lander, which crashed on the Moon on September 6. "During the second phase of descent, the reduction in velocity was more than the designed value," said a government space official. He continued, "Due to this deviation, the initial conditions at the start of the fine braking phase were beyond the designed parameters . . . As a result, Vikram hard landed within 500 meters of the designated landing site." In layman's terms, something went wrong with the braking thrusters, and the lander augured-in. Here's to success on the next attempt.

IT JUST KEEPS GOING, AND GOING

For anyone concerned that Jupiter may lose its giant Red Spot, rest assured—it's not going anywhere soon. Though shrinkage of the ruddy cyclonic storm has been observed since the 1800s, it's still going strong. What we actually see are cloud tops that are reacting to a storm system below. The dynamics of that storm are incredibly complex, and experts suggest that the changes we observe are more evolutionary in nature than anything else. "These are very normal healthy activities for the Red Spot and its colleagues," said one researcher at a recent meeting of the American Physical Society's Division of Fluid Dynamics. So rest easy—the largest storm in the solar system is secure.



1

Jupiter's iconic red spot, seen to lower left.
Credit: NASA

GET OUT OF NORMAL!

Anthony Paustian, Ph.D.

In *Star Trek*, Captain James T. Kirk would close his voice-over at the beginning of each episode with the phrase "to boldly go where no man has gone before." These words inspired a generation of engineers, scientists, mathematicians, and designers—including women and people of color who took greater risks to achieve success. They also inspired some people to envision a world living in peace and striving to understand its place in the larger scope of the universe.

Star Trek was the brainchild of Gene Roddenberry. Unlike many creators of science fiction, who tend to look at the future through the lens of the present, Roddenberry imagined an entirely different universe, one where people have put their differences aside and come together for the betterment of all. In contrast to his contemporaries, instead of asking, "What *can* we do?" he posited a different question: "What *should* we do?" For Roddenberry, it was important to imagine not only what society could look like once people lived together in peace, but also a future based on scientific concepts that were somewhat plausible extensions of existing 1960s technology.

As with Roddenberry's *Star Trek*, virtually everything in our lives outside of nature itself was conceived through someone's imagination. Through the art of abstraction and elaboration, imagination allows one to visualize that which doesn't exist. Unlike creativity, which is connecting what already exists in new ways, or innovation, which is the useful application of that creativity, imagination is the underlying current or mental "flow" that ultimately moves ideas through the creative and innovative processes.

Science fiction often disrupts the status quo and requires audiences to reject current reality along with its accepted ideas and methods. For example, in the decades prior to the Apollo missions, traveling to the Moon was imagined only by writers of science fiction. Years later, science fiction became fact when Neil Armstrong took his "giant leap for mankind" onto the lunar surface. In similar fashion, based on what Roddenberry and his team imagined with *Star Trek*, an inspired fan base would go on to turn many of the technologies imagined in the series into reality.

The cell phones of the late 1990s look strikingly similar to the handheld "communicators" used by Captain Kirk and his crew. GPS systems and the voice features of Apple's Siri, Amazon's Alexa, and Google's Assistant sound a lot like the female computer voice on the show. Video-based communication between people on the bridge of the *U.S.S. Enterprise* with those from other worlds or ships is prescient of FaceTime or Skype. The earpiece that Lieutenant Uhura used at her communication station closely resembles early Bluetooth headsets. *Star Trek's* flat, color video screens were introduced when large, black-and-white "tube" televisions were the norm. Spock frequently inserted memory cards into bridge consoles decades before compact flash cards existed. One could even argue that "beaming" has existed for some time now—paper documents have been "beamed" throughout the world using fax machines since the 1970s and through the use of

3D printers tangible items including mechanical parts, food, and even artificial human organs are now "beamed" through the air. In fact, this is how many items are currently sent to the International Space Station.

However, imagination isn't just in the purview of science fiction writers. To have any chance of returning to the Moon to stay, and to reach Mars and beyond, imaginative thinking and the subsequent creativity and innovation that come with it will require everyone involved to begin looking at things differently and to visualize new plans to achieve the goals of human space exploration and settlement.

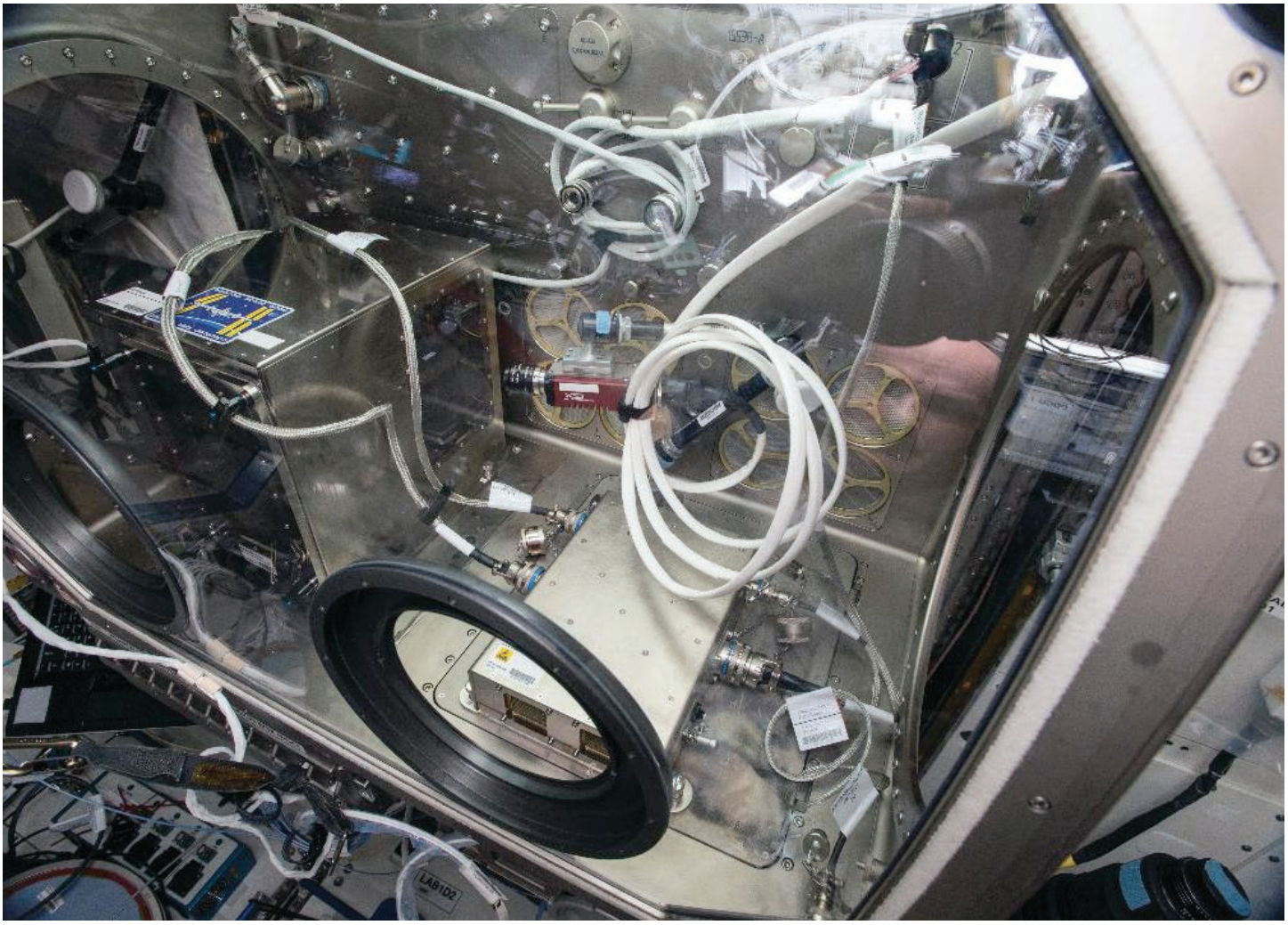
I frequently talk with people who profess that they aren't very imaginative or have difficulty with visualization. I believe the problem is more a matter of "don't" rather than "can't." Just as the average person cannot roll off the sofa and run a marathon without proper training, the ability to visualize requires preparation, practice, and the discipline to push yourself further. A number of strategies and activities can help to improve your ability to visualize new solutions:

ALLOW YOURSELF TO DAYDREAM: In a *Psychology Today* article discussing brain-scanning technology, researchers found a correlation between robust daydreaming and intelligence. In other words, allowing one's thoughts to bounce around while accessing stored knowledge creates stronger memories and experiences. Those with higher intelligence allow this process to occur, enabling them to yield greater insights as a result. Some of history's most brilliant people—from Mozart to Einstein—have credited their imaginations as the source of their intelligence. To enhance the benefits of daydreaming, one must allow time for it, acknowledge when it's happening, and even have paper nearby to take notes for later reference.

LEARN NEW THINGS: The process of creativity or "sticky thinking" requires an ever-growing base of knowledge available for one to access and make new connections. Imagination and visualization are no different. Since visualizing things often depends on mentally altering things you already know, a large base of knowledge and personal experience will greatly enhance the ability to see new things in the abstract. It's not difficult to visualize a red elephant if you have already seen elephants and various shades of the color red.

TRY TO FOCUS: I'll never forget when I took my daughter to see the IMAX movie *Hubble*. The movie featured a space shuttle mission to repair the Hubble Space Telescope while in orbit and displayed a number of the breathtaking images taken by the telescope. When viewed on the immense OMNIMAX screen, the movie seemed larger than life and

Star Trek creator Gene Roddenberry holding a model of the *U.S.S. Enterprise*.
Credit: Getty Images. Used with permission.



The 3D printer used on the International Space Station.
Credit: NASA

captivated my then 17-year-old daughter's attention. She was engaged and asked questions for about 15 minutes until she received a text message and some Facebook updates. Today, when it seems many of us lack the inclination to focus on one thing for very long, it's no wonder people struggle to visualize new worlds or complex concepts.

ASK QUESTIONS: The great educational theorist John Dewey once said that a problem properly defined is half-solved. When one applies "sticky thinking" to a properly defined problem, the odds are greatly improved for developing better solutions. However, properly defining a problem is typically more difficult than it sounds. It requires stimulating, open-ended questions that facilitate making new connections. Questions like *why, what if, what would that look like*, and *what would it take* can help one see the larger context surrounding the problem and better visualize how to solve it. A simple question led to the invention of the Polaroid camera, after a 3-year-old girl asked to see a photo of her that had just been taken. A group of watermelon farmers in Zentsuji, Japan came up with a more efficient way to ship and store them when they asked the question, "What if we made the fruit square?"

GET OUT OF NORMAL: I bought a ticket to my first Comic-Con in 2015 with only one purpose in mind: to meet William Shatner, the "original" Captain Kirk. What I witnessed was amazing. Many of the participants were deeply involved in costume play (cosplay). Bright colors abounded, merchandise changed hands at a furious pace, comic book illustrators had their works on full, brightly-lit display, and gaming was in play everywhere. I began the weekend as an outsider who had only engaged in the outer fringe of this world. I got a taste of what it was like to immerse myself in a unique subculture, one where the focus was imagination and the willingness to immerse yourself in worlds that don't exist anywhere except in the minds of the people who created them. People need to "get out of normal" and allow themselves to see things differently. Comic-Con was anything but normal for me, yet I found it incredibly motivating. We all need a place to "escape" to that opens our minds to new things and inspires us to greater levels of imagination and creativity.

As throughout much of history, imagination transforms the world at record speed and shows no signs of slowing. Just as the Apollo program forced us to visualize our planet in a new way, returning to the Moon could ultimately seem like a "tiny step for mankind" once we're standing on Mars and other, more distant worlds.

Paustian will chair the "Science Fiction to Fact" track at ISDC 2020. He can be contacted via his website, www.adpaustian.com.

Buzz on Mars.
Credit: James Vaughan

ALDRIN AT 90

Rod Pyle

STILL AIMING HIGH

Buzz Aldrin stood in the open hatch of the Gemini 12 spacecraft, watching Earth slowly pass below him. The view was spectacular—he'd been warned it would be mesmerizing, and that staying focused on his tasks could be a challenge. As his eyes were drawn by the sparkling teal blue of the oceans and the dazzling white cloud cover, somewhere down there, over 130 miles (209 kilometers) below him, technicians were already working on the Apollo Command Module that would soon carry astronauts to the Moon. While he hoped that he would be among those chosen, he had no way of knowing just how life-changing that assignment would be.

After taking some photographs and collecting a micrometeorite experiment mounted near the hatch, he had a few minutes to simply marvel at the incredible view. Then, as he held his glove near his helmet, he noticed something completely unexpected.

"During the second night EVA pass I saw blue sparks jump between the fingertips of my gloves," he later said. "Space clearly was not just an empty void. It was full of invisible energy: magnetism and silent rivers of gravity. Space had a hidden fabric, and the fingers of my pressure gloves were snagging the delicate threads." It was November, 1966, and although he did not know it at the time, in just under three years he would be standing on the surface of the Moon.

When one sits down to interview Aldrin, it's not a trivial affair; even at 90 years of age he is still at the top of his form. Once he gets rolling the ideas come fast, and you'd better keep up, because he's not slowing down. Every time I've interviewed him, he's continued to refine ideas he has been working on for years, as well as coming up with new ones. These range from better ways to explore the solar system (preferably with humans), new systems that will accelerate our journey to Mars, and new ways to engage and inspire young people.

Aldrin still stands ramrod-straight, speaks with energy and passion, and continues to generate new ideas. He recently founded the Human SpaceFlight Institute to seek more collaborative approaches to leaving our planet and create a global alliance of spacefaring nations to facilitate international cooperation in space exploration and development.

"I want to put together an advisory group with the National Space Council; a world alliance for space exploration that would include NASA, the European Space Agency, Japan, and China. Let NASA put it together, then the partners talk to each other about opportunities. NASA can then bring in ULA, SpaceX, and Blue Origin," he said during our recent conversation on the eve of his birthday. Ever pragmatic, he added, "Of course, this creates problems with vested interests, but if you supply the foreign markets and foreign contributions, a space exploration alliance makes more sense."

If this sounds ambitious, it is, but Aldrin is not a man of small ideas. As his son Andy once commented, "[Space is] absolutely his life's work . . . he never stops thinking about it." Aldrin is impatient to see humanity get back beyond Earth orbit and into the void between worlds.

Buzz was formally known as Edwin Eugene Aldrin Junior until he had his name legally changed. He was born on January 20, 1930 into a family wrapped in military tradition. His father had been an aviator during World War I, became the assistant commandant at the U.S. Army's test pilot school

Aldrin seen during a Gemini 12 EVA.
Credit: NASA

after that conflict, and had taken an executive position at Standard Oil by the time Buzz was born. He was a terse and demanding man who pushed his son hard. His mother Marion and two sisters completed the family. The younger of the two sisters influenced his life in more ways than one—her attempts to call him "brother" came out as "Buzzer," which was shortened to Buzz, a nickname that he later embraced officially.

Edwin Sr. had planned for his son to attend the U.S. Naval Academy in Maryland, and used political connections to pull an appointment to that institution as Aldrin neared high school graduation. But the younger Aldrin had other ideas—the straight-A football star of Montclair High School wanted to go to West Point, where the Army trained its officers. His father eventually relented, and in 1947 Aldrin went to study in New York.

West Point led to a commission in the Air Force, and by 1952 Aldrin was flying fighter jets in Korea. After shooting down two Soviet Migs and earning a number of flight medals, he was back in the United States for more training. After a three-year assignment flying jets in Europe, he enrolled at the Massachusetts Institute of Technology to study engineering, eventually leading to a doctorate in astronautics with an emphasis in manned orbital rendezvous. This was not strictly an academic decision. "The country was swept up in the space program, and I wanted to be a part of it," Aldrin recalls, "But NASA retained its requirement that astronauts have a diploma from a military test pilot school—not one of my credentials. Since I knew that the Moon landing program Kennedy had described would need astronauts with skills other than the ones they drummed into you at test pilot school, I opted for another eighteen months of intensive work on a doctorate in astronautics, specializing in manned orbital rendezvous."

He applied to be an astronaut upon graduation in 1963, but was not accepted due to his lack of test pilot credentials. Armed with his doctorate degree, he stayed with the Air Force, relocating to the Los Angeles Air Force Base to work on orbital trajectories for the upcoming Gemini program. He then applied to NASA a second time and was quickly accepted—he recalls vividly the phone call he received from Deke Slayton, head of the astronaut corps. "We'd sure like you to become an astronaut," Slayton said in a Midwestern drawl. Aldrin fired back an instant yes.

Each astronaut had a specialization in addition to their training duties; some monitored the work on Gemini and Apollo spacecraft, some oversaw the design of spacesuits, while others worried about the Lunar Module. Aldrin, unique among the astronaut corps with a Ph.D. in astronautics, concentrated on the design of rendezvous and orbital trajectories. With a separate crew capsule and lunar lander in store for Apollo, the art of rendezvous—not yet explored by either the United States or the Soviet Union—would be critical. If a lunar lander returning from the surface could not find and dock with the orbiting Apollo capsule, the mission would be in severe jeopardy. Since this was his specialization, Aldrin applied himself to studying the dynamics of spacecraft in lunar orbit.

Crewed Gemini flights began in 1965 with Gemini 3. The rendezvous and docking tests began with Gemini 6A and Gemini 7, with two capsules rendezvousing in orbit (they were not equipped to dock). Gemini 8 achieved the first docking with an uncrewed target stage in 1966, and from then on the goal was to rendezvous and dock with these targets—called the Agena—on each flight. It was tricky business, as the Gemini navigation computer was primitive and barely warranted the name, but the tests were largely successful.

Another critical part of the Gemini program was proving that astronauts could exit their spacecraft and perform vital tasks in space during extra vehicular activities (EVAs). Mastering this was considered essential for Apollo, but had

proved more elusive than rendezvous. The EVA attempts—which had not received the preparation they should have—resulted in fatigued, disoriented, and exhausted astronauts who were unable to accomplish all their goals. Aldrin's mission, Gemini 12, would be the last chance to get it right.

Aldrin was determined to perfect EVA to the best of his abilities. Alone among his colleagues, he spent countless hours over months training for it. The others had trained, but not to nearly this extent or with Aldrin's ferocity. He went up in the zero-g simulator aircraft again and again and used other NASA Gemini trainers, but was not convinced that this was enough to assure success. At that time, NASA had started experimenting with underwater training. It was just a nascent effort at this point; the space agency did not even have a large water tank for such activities, so it leased time in a pool at a nearby high school. Aldrin, already an avid scuba diver, seized on this—what would later become known as neutral-buoyancy training—and could be found day after day, sealed in a Gemini pressure suit, in the deep end of the pool clambering over the Gemini simulator sited there.

Then on November 11, 1966, it was time for him to prove his mettle. Gemini 12, the last flight of the program, launched shortly after the Agena target vehicle with which it would rendezvous and dock. The first problems appeared within hours. Soon after the Gemini's radar acquired the still-invisible Agena stage, now 225 miles (473 kilometers) away, the onboard radar failed. Undeterred, Aldrin pulled out some navigational charts, a sextant, and a slide rule, and manually calculated where the Agena should be. "The fallback for this situation was for the crew to consult intricate rendezvous charts—which I had helped develop—to interpret the data using the 'Mark One Cranium Computer,'" Aldrin would later say. Commander Jim Lovell completed the docking using less fuel than previous flights, and they checked-off the manual rendezvous exercise, which had been scheduled for later in the flight.

A day later, Aldrin's second EVA would be a true test of his preparations. Leaving the Gemini capsule, he carefully made his way first to the Agena to set up an experiment, and then moved back to the rear of the capsule to an experimental station the astronauts called "the busybox." Once there, Aldrin performed the tasks that had so vexed his predecessors, torqueing bolts and adjusting fixtures. It went like clockwork. As he later said, "Project Gemini had finally triumphed. All of its objectives had now been met. We were ready to move on to Project Apollo and the conquest of the Moon."

Crew selection for Apollo 11 came in 1968 during the flight of Apollo 8. Neil Armstrong would be the commander, Aldrin the Lunar Module Pilot, and Mike Collins the Command Module Pilot. The trio threw themselves into intensive training for the mission, now just six months away. On July 16, 1969, everything that could be done to prepare for the first landing attempt had been done, and at 9:32 am Eastern Time, they were off—Apollo 11 bolted into a perfect blue Florida sky. Three days and a harrowing landing later, Aldrin and Armstrong were on the lunar surface, ready to explore the Moon.

Aldrin and Lovell boarding their spacecraft for their capstone Gemini mission.
Credit: NASA

They suited up and opened a valve to depressurize the Lunar Module's cabin, but when they tried to open the hatch, it would not comply. After looking at the pressure gauge and trying again, it was still inoperable—the hatch would not budge. There was still just a bit too much air pressure inside the cabin. Aldrin was nonplussed. "We didn't fly 240,000 miles to *not* explore the Moon," he later told me. "I reached down and grabbed the corner of the hatch and flexed it back—there was a hiss of escaping oxygen, and it swung open . . . You do want to be a little careful about not bending that door," he added with a smirk.

Armstrong got out first, inadvertently breaking a small plastic switch as Aldrin maneuvered him out of the hatch. Aldrin then followed him down the ladder about 20 minutes later. While Armstrong went down in the history books for his famous first words on the Moon, Aldrin would prove to be among the most poetic of all the Apollo astronauts. As he turned away from the ladder to step onto the surface, he said, "Beautiful view." Armstrong retorted, "Isn't that something? Magnificent sight out here." After a pause, Aldrin replied, "Magnificent desolation." It was a perfect—and lyrical—description of the lunar surface.

For the next two and a half hours the pair gathered rocks, set up experiments, and took photos and measurements as laid out by a very aggressive timetable. Then Aldrin went back up the ladder, followed by Armstrong. They sealed the LM, cleaned up, and then noticed the broken switch on the floor—it was the ascent engine arming breaker, the very switch they would throw to return to lunar orbit. While the astronauts rested, Mission

Control developed a workaround to bypass the switch, but as they prepared for lunar liftoff about 10 hours later, the ever-pragmatic Aldrin looked at the breaker—now just a plastic hole in a panel—pulled a felt-tipped pen out of his pocket, and jammed it inside. The switch closed and they were soon ready to go—problem solved for less than the cost of a beer.

Less than three days later, they were bobbing in the Pacific Ocean awaiting pickup by the Navy. But their ordeal was not over, as they would have to don biocontainment suits before getting out of the capsule and then spend the next three weeks in quarantine to ensure they had not brought any dangerous germs back from the Moon. "It was a bit of a blessing," Aldrin later said. "We had time to decompress." At one point during their lockdown, Armstrong and Aldrin were watching recorded footage of the Moonwalk. Aldrin smirked, turned to Armstrong and said, "Neil, you know what? We missed the whole thing!" In a sense, he was right—they had been so busy completing their lunar chores there had been little time for it to soak in.

After a whirlwind tour of the United States and 25 world capitals, the crew went their separate ways. Armstrong secured a teaching appointment in aeronautical engineering at the University of Cincinnati, while Mike Collins eventually became the head of the Smithsonian Institution's National Air and Space Museum, but Aldrin's post-NASA life took a different trajectory. As they recovered from the tour, Collins noted that Aldrin had seemed withdrawn, almost depressed.

Over the following years, Aldrin struggled with depression and eventually alcoholism. A divorce soon resulted, and then two more marriages came and went. But neither the relationships, three wonderful children, nor the various assignments he received seemed to help—Aldrin was struggling to find new relevance in his life after the mission of Apollo 11. As he later wrote, "I wanted to resume my duties, but there were no duties to resume," adding, "There was no goal, no sense of calling, no project worth pouring myself into."

Buzz at 90.
Credit: Buzz Aldrin

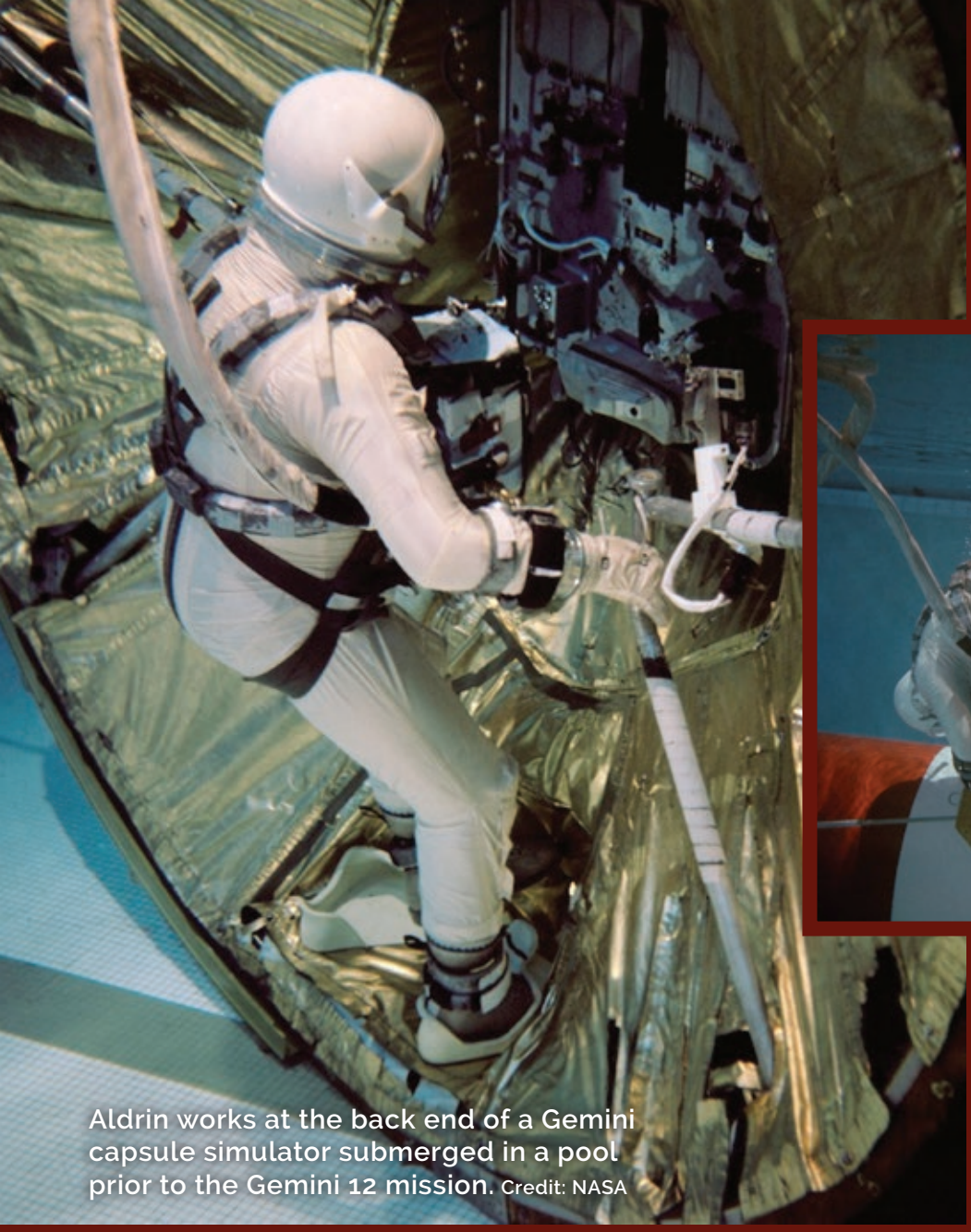
In his books about his career and the missions of Apollo and Gemini, Aldrin spoke openly about his struggles with depression and alcohol—an incredibly bold step during an era in which combat pilots and astronauts did not discuss such things with each other, much less announce them to the public. But Aldrin felt it was important for the world to know about the pressures that people such as himself worked under, and is was likely a cathartic process for him as well.

By the 1980s, things were improving. Aldrin had written a number of books, was energetically pursuing his agenda of advancing the human presence in space, and had become somewhat of a media figure. There were appearances on numerous television shows, autograph signings, and a demanding schedule of talks and other media appearances. He has served tirelessly on the Board of Governors of the National Space Society since the mid-1980s. But always, his core ambition has been to push the development of human spaceflight beyond Earth orbit.

He recently told me, "About 1985, I began looking at how we might go to the Moon and Mars with free return trajectories—to swing around and return from these places, and this led to the cyclers." His Aldrin Cycler employs a large spacecraft that would be placed into a continuous, looping trajectory between Earth and either the Moon or Mars, with smaller shuttles carrying crew to and from the cycler. In this way, the cycler acts as a continuous transport (with comfort and radiation protection for its crews) with shuttles or "taxis" moving passengers and cargo from the cycler to Earth, the Moon, or Mars. It's a brilliant plan, and one that he will describe to anyone willing to listen.

Aldrin is still a vibrant force for expanding the human presence in space.

Aldrin, on the left, and Lovell, after Gemini 12 recovery.
Credit: NASA



Aldrin works at the back end of a Gemini capsule simulator submerged in a pool prior to the Gemini 12 mission. Credit: NASA

Aldrin works his way to the forward intersection of the Gemini/Agena vehicle simulator prior to the Gemini 12 mission.
Credit: NASA

Alone among the Apollo astronauts, he has continuously—and vigorously—campaigned for NASA to continue its journey beyond Earth orbit. He is also a prominent voice for internationalism in space, pushing for greater collaboration with a number of nations, especially China. Aldrin has traveled the globe tirelessly to deliver this message, and recently formed the Human SpaceFlight Institute to continue his efforts. He serves with the National Space Council, a NASA advisory group, and is working to form a global alliance for space exploration. "I'm very interested in dealing with international groups, and I've heard people discussing this over in China—'How should we come together?' It's very crucial to not have a competition with China. We can work together."

In the numerous interviews I've conducted with him for this article and many books, Aldrin is always engaging and energetic—he is a true force of nature. The ideas and plans come fast and furious, as he continues to work towards his final legacy: humanity's greatest adventure. "Fifty years after Apollo, what can we actually do?" he recently said. "The Space Launch System won't [initially] even be able to get the Orion capsule into a proper lunar orbit with any real maneuvering capability, so rather than a direct landing, Orion will enter a rectilinear lunar halo orbit, where NASA has planned to place the Lunar Orbiting Gateway—a program forced to accommodate Orion/SLS's limited capabilities as planned."

"I'm not a fan of the Gateway," he told me, "We don't need a permanent orbital structure at the Moon!" Instead, he thinks that the core of the Gateway could be used as a transit vehicle between Earth and the Moon if properly developed. "If that's not a winner, I don't know what is," he said. But he then summed up the interactions between people like himself and NASA with a chuckle, "It's hard to mix fighter pilots with managers." That may be true, but after nearly half a century of developing ideas to return humans to deep space, his ideas seem to be increasingly relevant.

Happy birthday, Doctor Rendezvous!

ARE SPACE SETTLEMENTS EASIER THAN WE

Nancy Atkinson

A 1970s visualization of an O'Neill Cylinder interior with a 20-mile view down the long axis.
Credit: NASA Ames/Rick Guidice courtesy of NASA.

THINK?

Say the words "space settlement," and most people familiar with the term will invariably and immediately think of Dr. Gerard K. O'Neill, the late professor of physics at Princeton University.

"There are good reasons for that," said Al Globus, a space settlement designer and author. "O'Neill's vision of humankind's expansion into space has inspired many people for many years, especially because of his book *The High Frontier: Human Colonies in Space*." O'Neill's seminal book, published in 1977, envisioned large habitats in free space located at Lagrangian points, regions where the gravitational forces between the sun and Earth (and Earth and the Moon) produce stable "parking spots."

O'Neill suggested various designs for the habitats: massive spherical and torus-shaped structures, plus a distinctive design that has come to be known as O'Neill Cylinders. These consist of a pair of tubes, each as large as 20 miles (32 kilometers) in length and four miles (6.5 kilometers) in diameter. The total land area inside a pair of cylinders is about 500 square miles (1,300 square kilometers) and they could house several million people with enough acreage for farming to feed the inhabitants. The cylinder's huge size means a gentle spin of one revolution per minute-and-a-half would simulate terrestrial gravity. Children could be born and people could live out their lives in space in one of these colonies and not suffer any of the debilitating effects on muscles and bones that come from living in microgravity.

In O'Neill's vision, all of these designs could be constructed using raw materials from the lunar surface or near-Earth asteroids, with the materials launched into space using a mass driver and then directed to the colony's location. The habitats would be illuminated and powered by the sun, and solar power satellites could serve to support the habitats.

"O'Neill's vision was beautiful, innovative and wonderful, and it has endured for decades," said Globus. "He showed that space colonies are technically feasible. But these settlements are gigantic, several kilometers across, they weigh millions of tons, and could be over 380,000 miles (600,000 kilometers) away. Now everybody is wondering why they haven't been built yet."

"The reason is, they are too darned hard," continues Globus, a former contractor and researcher at NASA's Ames Research Center, who has been a long-time fixture in the space settlement community, especially the National Space Society. "These ideas are way too hard to pull off. The space settlements envisioned are too big, too massive, and too far away to be practical, at least as a place to start."

Floor level of a rotating space habitat.
Credit: Bryan Versteeg

Adding to the enormous effort is the fact that the inhabitants would need to be protected from the high levels of radiation in deep space, as inadequate shielding could lead to cancer, cataracts, and sterility. According to research by Globus and others, radiation protection at the Langrangian points requires about seven tons of water or 11 tons of lunar regolith per square meter on the hull of a structure.

"This amounts to millions of tons of extra material for a settlement," Globus said. "It would be completely impractical to transfer all that material from Earth. You'd have to build up an extensive extraterrestrial industrial base to take advantage of lunar or asteroid materials, involving an electromagnetic catapult, and construct all that even before the habitat could be built and the first settlers could move in. It would be like having to build a cement plant and a lumber mill before building one house here on Earth."

Due to the shielding requirements, the mass for that protection completely dominates that of any space settlement design and exponentially increases the difficulty in building such a structure. But it turns out there might be an easier way to build space settlements. Research by Globus and his colleagues reveals some new developments that could reduce the size and the amount of radiation shielding necessary.

"We found that two of the main assumptions about space settlements are not quite as ironclad as originally thought," Globus said. "In combination, this could reduce the mass requirements by a factor of about 100, which would make settlements much easier to build."

Globus worked with space policy expert Tom Marotta to detail the specifics and potential consequences in a new book geared towards general audiences, *The High Frontier: An Easier Way*. This book is both an homage to what O'Neill achieved (the authors received permission from Tasha O'Neill, the professor's widow, to use *The High Frontier* in the title) as well as a timely update to his vision. The impetus behind the research came when Globus learned how to use a NASA program called OLTARIS (On-Line Tool for the Assessment of Radiation in Space) to study the effects of space radiation on humans and electronics.

"Just for kicks, I did some calculations [for siting in] deep space, looking to see how much shielding and what kind of material you'd need," Globus recalled. "Then, on a lark, I tried seeing what radiation levels were in low Earth orbit (LEO). I really wasn't thinking about any specific orbit, but if you go into OLTARIS, the default inclination is

zero, so I just left it there. Surprisingly, I got these amazing numbers coming out, which was really exciting. I worked with Ted Hall from the University of Michigan and Daniel Faber, co-founder of Orbit Fab, to verify the calculations across several different scenarios."

What Globus and his colleagues found is that that there is a region of space in Earth orbit, called equatorial low Earth orbit (ELEO), which is close to the planet—about 311 miles (500 kilometers) above the surface—where the radiation levels are very low. "It is a low inclination orbit, less than five degrees," Globus said, "and the calculations show that even in a very bad radiation year, the radiation levels in a space settlement there would likely be less than 20 milli-Sievert (mSv) per year."

Unchecked, space radiation may place astronauts at significant risk for radiation sickness, cancer, and other degenerative diseases. During NASA's spaceflight history, astronauts have been exposed to ionizing radiation with doses between one and 2,000 mSv. Recent data collected by NASA and a Russian-Austrian collaboration show that astronauts on the International Space Station (ISS) are subjected to one mSv of radiation per day, about the same as someone would get from natural sources on Earth in a whole year.

"NASA works with the same exposure limits as those set by the U.S. Environmental Protection Agency for radiation workers on Earth, and 20 milli-Sieverts per year is one of the occupational thresholds for nuclear workers and other technicians," Globus explained. "After extensive review, my co-authors and I came to the realization that this is a good level for space settlements to stay below."

Radiation levels in low Earth orbit are quite low over most of the globe, with the exception being a region in the southern hemisphere called the South Atlantic Anomaly. This area of space is where the ISS astronauts receive almost all their radiation exposure. "If your settlement stays in equatorial low Earth orbit, you avoid passing through the South Atlantic Anomaly," Globus said, "so radiation levels in this type of orbit are much lower than for the ISS."

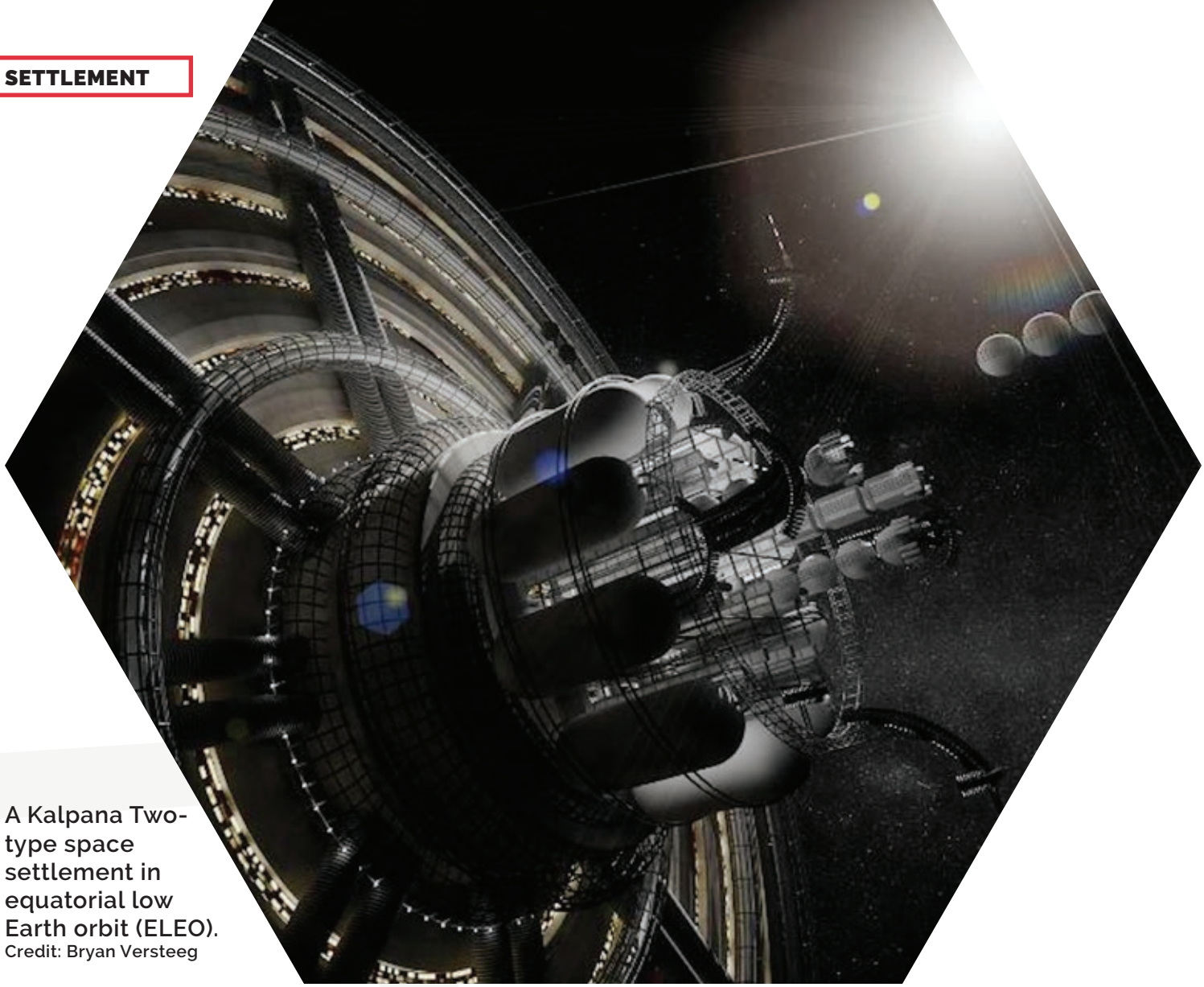
Space radiation comes from solar activity in the form of intense but short-lived particle events, as well as galactic cosmic radiation originating beyond our solar system from dying stars. Earth naturally shields objects in low Earth orbit with its mass and also generates a magnetic field that deflects high energy particles.

"It turns out that Mother Earth will protect you if you stay by her side," Globus said, smiling. "If you build an O'Neill settlement in ELEO and get rid of the radiation shielding—because you don't need millions of tons of shielding material—you shed somewhere between 94 to 99 percent of the mass of the structure. Plus, you don't have to build up an entire Moon-mining operation. The consequence is that launching all the materials from Earth for small space settlements may actually be practical in the relatively near future."

The second potential improvement to O'Neill's concept is a new look at the rotation rates of a space settlement in order to create simulated gravity. This would not only provide an Earth-like feel to a settlement, but also mitigate negative health effects from living for long periods in microgravity. "At the time O'Neill was researching space settlements in the 1970s," Globus said, "the general understanding was that you wouldn't want to rotate any structure more than one to two rotations per minute to avoid motion sickness."

The faster a settlement rotates, the smaller it can be and still provide artificial gravity at the exterior rim. Globus said that to achieve the equivalent of Earth's gravity, one to two rotations per minute implies a settlement radius of approximately 750

Life goes on as usual in a rotating space habitat.
Credit: Bryan Versteeg



A Kalpana Two-type space settlement in equatorial low Earth orbit (ELEO).
Credit: Bryan Versteeg

to 2,000 feet (225 to 895 meters), which is much larger than any existing satellite. But a closer examination of O'Neill's later work shows he came to the conclusion that three rotations per minute would be perfectly acceptable. Additionally, more recent research during the space shuttle program shows that between four and six rotations per minute would be acceptable.

"There are good reasons to believe that much higher rotation rates may be acceptable to space settlement residents and visitors alike, significantly reducing the minimum size of settlements and thus the difficulty of building them," Globus said. "Not that people won't get space sick at the beginning, but your body will adapt and you'll get better in a few hours or days, depending on how susceptible you are to space sickness. So, moving into a space settlement might be a bit like moving to Nepal and getting altitude sickness. You might feel terrible at first, but when your body adjusts you'll be fine."

Globus' research finds that rates of up to four rotations per minute correspond to a radius of 184 feet (56 meters), which should be acceptable—although visitors may require some training or a few hours to a day of adaptation. A rate of up to six rotations per minute (and an 82-foot or 25-meter radius) should also be acceptable for residents, but visitors will almost certainly need training or a few days to adapt.

The reduction in mass for less radiation shielding, reduction in size due to an increased rotation rate, and a location closer to Earth changes the outlook on how difficult it will be to build the first space settlements. "Instead of looking at millions of tons for a settlement, with distances far, far away," said Globus, "now you're looking at a nearby settlement with a mass of about 8.5 kilotons, which is only 20 times the mass of the ISS. The net effect is you get a radical reduction in the cost and difficulty, orders of magnitude less." This also means that space settlements could potentially be built sooner.

"As someone who has followed the space settlement concept for decades," said Marotta, "I've routinely read Al's research. And when I saw his recent papers, I thought to myself, *this is it! This is a really big deal*. When you pair Al's findings with the recent improvements in launch capability, public policy and space investments, there is a perfect storm happening. Space settlements could happen decades from now, not centuries."

Globus already has a concept in mind for the first space settlement in equatorial low Earth orbit. Called Kalpana Two, the settlement would be named after Kalpana Chawla, American astronaut and the first

Indian-born woman in space, who died tragically in the space shuttle *Columbia* accident in 2003. Chawla worked at the Ames Research Center and had an office just down the hall from Globus. Kalpana Two would be a 328-foot (100 meter) diameter cylindrical settlement with a mass of around 8.5 kilotons. Unlike the ISS, the structure would not be a few capsules connected by tunnels, but an open living area comparable in size to a large cruise ship, with Earth-like gravity just inside the hull and a zero-gravity recreation area at the axis of rotation.

With the current regulatory environment enabling commercial space stations and orbital space settlements, Globus and Marotta envision condominiums in Kalpana Two, where people could purchase homes. A space version of AirBnB would likely follow, but it all comes down to making the cost viable. "In the worldwide market for real estate," Marotta said, "there are hundreds of thousands of real estate transactions globally above one million dollars every year. So, once the price gets down to one to three million dollars, the market size becomes viable."

Of course, before Kalpana Two becomes a reality, several hurdles and technology development challenges remain. All space settlements will need new types of power systems, thermal control, communications, life support, and materials recycling, to name just a few. But two challenges stand out for Globus and Marotta: space farming and the all-important transportation issue.

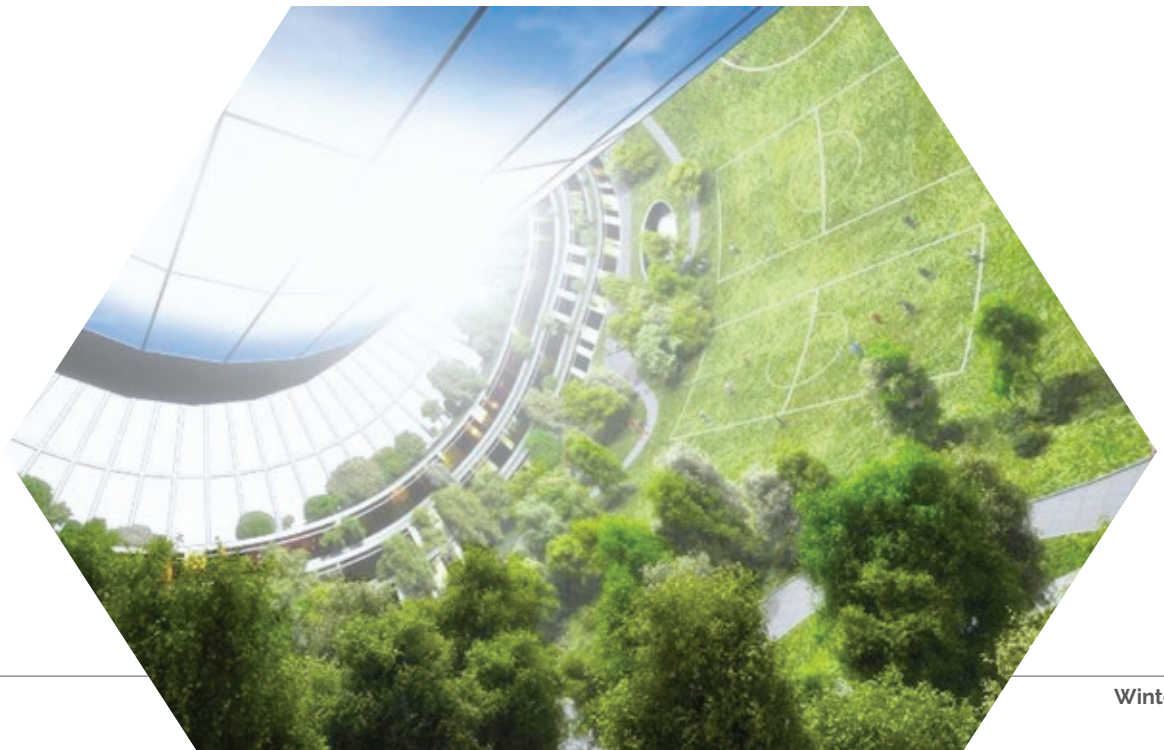
"Space farming is very challenging for large scale orbital space settlements, but growing food in space is necessary to make settlements self-sustaining," Marotta said. "Early indications from some of the experts indicate that the challenge will not come in having sufficient oxygen but having sufficient carbon dioxide to feed all the plants. This is totally counter-intuitive, at least to me, but indicative of how much we need to learn about closed environment life support systems."

However, the idea of space farming is already being worked on here on Earth with concepts like vertical farming, hydroponics, and the use of specialized greenhouses for growing crops in less-than-ideal conditions. Even though ISS astronauts have grown some flowers and a few leaves of lettuce, Globus and Marotta suspect that some of the next-generation space stations will solve the challenges currently facing space farming. But it all comes down to the biggest hurdle, having reliable transportation to space and getting the costs down to where more materials can be transported and more people can fly affordably.

"While transportation has always been the hardest problem," said Globus, "I want to emphasize that it is really being worked right now, and worked hard. By a huge margin, this is the golden age of rocketry. There are over 100 companies developing launchers. Once the price of access to transport yourself and your stuff to space gets down to what SpaceX is optimistically saying for Starship or Blue Origin for New Glenn, then we're off to the races."

Current costs for a ride to space is between 30 to 50 million dollars per person. The most optimistic predictions of SpaceX's Super Heavy show transportation costs of getting to Kalpana Two could eventually be reduced to about 1.25 million dollars per person. "That's a lot of money, but that's a figure that makes it possible for more people," Globus said. "Maybe we'll have to wait for another generation of vehicles that are even better than Starship or the Super Heavy to help reduce costs. But it is at least plausible that we could make it work."

A close reading of *The High Frontier: An Easier Way* shows that Globus and Marotta are careful not to overhype their conclusions, only saying that progress is being made and space settlements now look to be easier. "The idea of the book is not to get people hyped-up to say this is a foregone conclusion," said Globus. "There is still a lot of work to be done, but we now have a vastly better chance of building a space settlement in the next few decades. Once you build the first one, it gets easier from there. One day, we'll get to what O'Neill had envisioned."



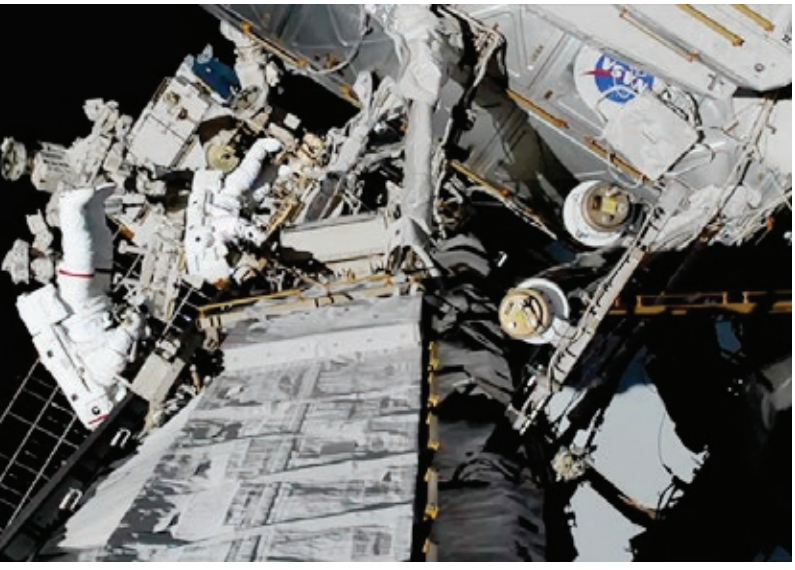
An ELEO settlement, with a solar-powered lighting element at upper left.
Credit: Bryan Versteeg

Credit: NASA

A SPACEWALKING FIRST

AN ALL-FEMALE CREW

Melissa Silva



Replacing a power controller on the ISS during the first all-female EVA.
Credit: NASA

On October 18, 2019, at 7:38 a.m. Eastern Time—in what will likely be one of the final firsts in Earth-orbital spacewalking—astronauts Christina Koch and Jessica Meir switched their spacesuits to internal power and made history, conducting the first all-female spacewalk. The astronauts were tasked with replacing a failed power controller on the International Space Station (ISS), and the extra vehicular activity (EVA) lasted a total of seven hours and 17 minutes. It was Dr. Meir's first spacewalk and Koch's fourth.

Koch was originally scheduled to perform an EVA with astronaut Anne McClain to upgrade the power systems of the ISS on March 29, 2019. However, due to a recommendation made by McClain pertaining to the mismatched size of her spacesuit, the spacewalk was reassigned to astronaut Nick Hague, who joined Koch as they updated the station's power technology.

Dr. Meir was born and raised in Caribou, Maine and holds a doctorate in marine biology from the Scripps Institution of Oceanography. Prior to being selected by NASA in 2013, she conducted research on the physiology of animals in extreme environments and took part in numerous diving expeditions, including a Smithsonian Institution expedition to Antarctica and Belize. From 2000 to 2003, Meir worked for Lockheed Martin's Human Research Facility supporting human physiology research on the space shuttle and the ISS, participated on research flights on reduced gravity aircraft, and served as an aquanaut crew member for the fourth NASA Extreme Environment Mission Operations mission. Dr. Meir is also the first Jewish woman to perform a spacewalk and is being celebrated among Jewish communities worldwide.

Koch was born in Grand Rapids, Michigan and holds a Master of Science in Electrical Engineering from North Carolina State University. Prior to becoming an astronaut in 2013, Koch worked in space science instrument development and remote scientific field engineering at the NASA Goddard Space Flight Center's Laboratory for High Energy Astrophysics, and later as a research associate for the United States Antarctic Program. She also worked with the National Oceanic and Atmospheric Administration as a field engineer and station chief. Koch is slated to set a record for the longest spaceflight by a woman, with an expected total of 328 continuous days in space, providing researchers the opportunity to observe the effects of long-duration spaceflight on a female to prepare for human missions to the Moon and, eventually, Mars.

Dr. Meir and Koch's spacewalk was the 221st EVA performed in support of space station assembly and meintenance. They replaced a battery charge and discharge unit that failed to activate after new lithium-ion batteries were installed on the space station's Integrated Truss Structure. These units regulate the charge put into the batteries collecting energy from the station's solar arrays. All three of Koch's previous EVAs have also dealt with the station's power and electrical power systems, making her the most qualified astronaut aboard the station for the spacewalk.

The spacewalk is one of a series scheduled to replace the station's original nickel-hydrogen batteries with new lithium-ion units that are part of the station's solar power network. The batteries' location makes it impossible to use either Canadarm2 or the Orbiter Boom Sensor System arm, as it does not have the grapple fixtures needed to remove and replace the failed battery charge and discharge unit (which will return to Earth for analysis).

The astronauts' spacewalk was celebrated around the world and generated much anticipation toward NASA achieving its goal of putting a man and the first woman on the Moon within a few years. "History was made today. Use this as an opportunity to inspire others and to be inspired. This is an important milestone in human spaceflight, and these women are both incredible role models for the future generation of space explorers," said Canadian Space Agency Flight Controller Kristen Facciol, who provided ground support from NASA's Mission Control at the Johnson Space Center in Houston, Texas.

NASA astronaut Tracy Caldwell Dyson, who has logged over 22 hours in three spacewalks, said, "I think the milestone is that hopefully this will now be considered normal, not to overshadow the fact that women have been doing spacewalks for 35 years. We train like this every day, so it's pretty normal, and we just hope that this is a start to that."

Christina Koch bumps fists with Jessica Meir, who is suited up for the EVA.
Credit: NASA

DESTINATION MOON

Public-Private Partnerships Will Drive Lunar Architecture

John F. Kross

In the fifty years since the first lunar landing, the bones of Apollo have been picked clean by the media, academics, and even critics, with nearly every rivet cataloged and evaluated. The race to the Moon was ambitious, captivating, and exhilarating, but epitomized a top-down government approach that ended human missions to deep space for at least five decades. The Apollo program was shaped and guided by government bodies, most directly NASA, coordinating the nation's resources to achieve a national goal by a specific deadline. Private industry was crucial to the quest, but not determinative.

Five decades later, the environment has fundamentally changed, with space entrepreneurs and companies now seminal to America's drive to send humans beyond Earth orbit. NASA increasingly recognizes the central and expanding role of the commercial sector, and public-private initiatives between NASA and commercial players have emerged as a favored model for sustained human movement into deep space.

BUDGETING TIME AND DOLLARS

Leveraging commercial space was a major theme throughout the *National Space Exploration Campaign Report* that outlined the nation's drive to the Moon and Mars. The initial project proposed by NASA was the modular Lunar Orbiting Gateway (also known as the "Gateway") to reside in a near-rectilinear halo orbit around the Moon. In early 2019, the U.S. space agency unveiled its original lunar landing architecture incorporating the Gateway and other elements. The proposed sequence of missions was coherent, if complex and protracted, and relied heavily upon the Block 1B Space Launch System (SLS), featuring the Exploration Upper Stage (EUS). The biennial mission cadence culminated in boots on the Moon by the end of the 2020s.

This decade-long campaign received a chilly reception from the National Space Council's advisory group. "Personally, I think 2028 for humans on the Moon . . . just seems like it's so far off," said former shuttle commander Eileen Collins. Apollo 17 astronaut Harrison Schmitt added, "We can do it sooner." The tempo of the projected program, he noted, paled in comparison to Apollo. "I think of launching Saturn Vs every two months and you're barely going to launch [the SLS] every two years."

Already facing headwinds from the National Space Council, the initial architecture also ran up against the Trump Administration's 2020 NASA budget proposal, which deferred work on the more powerful Block 1B SLS. Minus the EUS, the SLS is unable to lift multi-ton cargo (such as Gateway or lander elements) together with Orion. Instead, the budget blueprint focused on completing the "initial version of the SLS and supporting a reliable SLS and Orion annual flight cadence." This language reflected a wish to finalize the oft-delayed Block 1 SLS as soon as possible. At the same time, the budget proposal promoted commercial launches of heavy payloads, including components of the Gateway, which "would be launched on competitively procured vehicles, complementing crew transport flights on the SLS and Orion."

The concept of a mixed fleet of commercial and government rockets has increasingly gained traction within NASA. Agency chief Jim Bridenstine has touted

his support for commercial spaceflight as well as cooperation between the public and commercial sectors. Even William Gerstenmaier, the former NASA associate administrator for human exploration and operations, gave his nod of approval to a diverse lineup of commercial and government rockets. "This is a great way to be," Gerstenmaier said. "I love every one of these rockets."

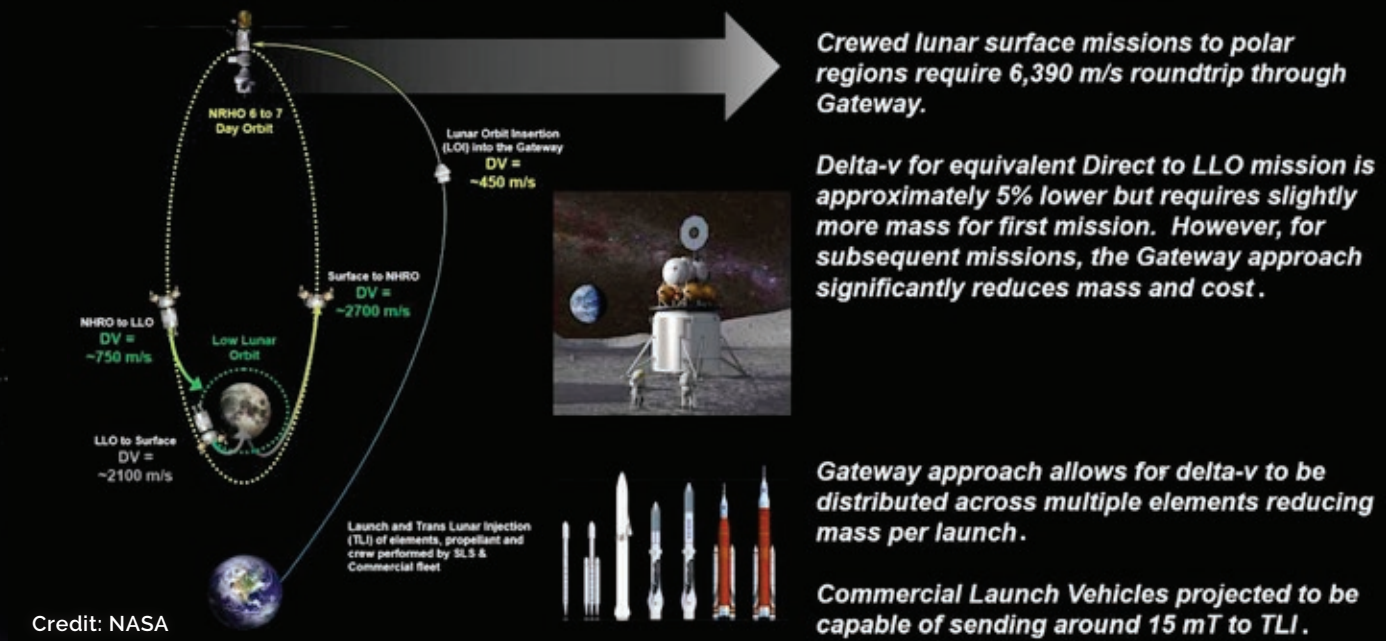
WHO'LL DO THE HEAVY LIFTING?

Current and proposed commercial launchers can boost much of the hardware and logistics for the Gateway and lunar lander. While official size and performance specifications are not yet final, NASA has published preliminary parameters for lunar landing elements. For example, a NASA Broad Agency Announcement set "preliminary goals" for a Descent Element and Transfer Vehicle at 16.5 tons (15 metric tons) "wet mass" (fully-fueled), fitting within a 15-foot (4.6-meter) payload fairing. A fueled Ascent Element could tip the scale at 9.9 to 13.2 tons (9 to 12 mT) according to other NASA documents.

These mass ranges are within the payload performance of some commercial vehicles. Unofficial performance calculations indicate that an expendable Falcon Heavy can boost 23.3 tons (21.1 mT) to lunar distances (Trans-Lunar Injection, or TLI). In booster recovery mode, the Falcon Heavy's payload capacity is 17.7 tons (16.1 mT) according to some informal computations. Publicly, NASA estimates are more conservative tagging

Artemis EVA
Credit: NASA

Lunar lander ascent stage liftoff
Credit: Boeing



Credit: NASA

the performance of an expendable Falcon Heavy at 16.9 tons (15.3 mT) to the Moon's vicinity. In either case, an expendable Falcon Heavy could lift Gateway or lander elements to the lunar neighborhood. Moreover, Falcon Heavy's payload fairing has a 17-foot (5.2-meter) diameter thereby meeting the volume requirement for lunar lander elements.

Given limited technical data, unofficial payload computations for proposed vehicles are rough approximations. Nevertheless, one estimate for Blue Origin's future New Glenn vehicle predicts a payload of 8.5 tons (7.7 mT) to the Moon's vicinity in the two-stage reusable configuration. However, this estimate is probably overly conservative. Commercial launch vehicles like New Glenn are usually optimized to deliver satellites to Geosynchronous Transfer Orbit (GTO) and New Glenn's "Payload User's Guide" asserts the rocket can hurl 15 tons (13.6 mT) to GTO. From there, only modest inputs in delta-vee are needed to achieve lunar distance. New Glenn will also introduce a spacious 23-foot (seven-meter) wide payload faring with room for the bulkiest payloads.

Overall, the wealth of launch vehicle options offers unprecedented speed and flexibility to mission planners. In addition to lander elements, several current and proposed commercial vehicles could lift the Gateway's 5.5 ton (five mT) Power and Propulsion Element or ferry 4.9 tons (4.4 mT) of cargo to the Moon-orbiting outpost as specified in a request for proposals for logistic services.

HOW LONG DOES IT TAKE TO GET TO THE MOON?

Like proposed commercial vehicles, the lift capacity of the Space Launch System is still hypothetical pending its launch. The SLS has inched toward its maiden flight for the better part of a decade at a cost of more than two billion dollars per year (for both SLS and Orion). In that time, the launch date has moved inexorably into the future with virtually no chance of meeting its once-formal June 2020 launch date. Expecting further postponements, NASA's Office of Inspector General spoke out about the schedule margin for the SLS core stage, noting that "delays are likely as significant integration and testing activities . . . have yet to occur."

The response of NASA's leadership to the latest delays was dramatic and public. At a hearing of the Senate Commerce Committee, administrator Bridenstine declared that all options were on the table, including sidelining the SLS in favor of commercial launch vehicles for Artemis 1 (formerly called Exploration Mission 1). "SLS is struggling to meet its schedule," Bridenstine told the Committee. "We, as an agency, need to stick to our commitments," he added, referring to the latest launch date slippage. "If we tell you . . . we're going to launch in June of 2020 . . . then we should launch around the Moon in June of 2020," he added, referring to the latest launch date slippage. To speed Artemis 1 along, the agency examined a range of commercial launch scenarios, including dual launches of a Delta IV Heavy and Falcon Heavy as well as fitting a Falcon Heavy with an Interim Cryogenic Propulsion Stage, but these proposals suffered from logistical and technical challenges.

Frustrated by the delays, Vice President Pence delivered a rhetorical jab to the Space Launch System in its own backyard. Standing in front of a mockup of the Apollo Lunar Module at the U.S. Space and Rocket Center in Huntsville, Alabama, Pence stressed that the end matters more than the means. "The first woman and the next man on the Moon will both be American

An astronaut places instrumentation during an Artemis EVA
Credit: NASA

astronauts, launched by American rockets from American soil," Pence declared. "If American industry can provide critical commercial services without government development . . . we will buy them . . . If our current contractors cannot meet this objective, then we will find ones that will," he warned. Then the vice president raised the stakes further by challenging the space agency to put boots on the Moon's south pole by 2024 as part of Project Artemis (named after the Greek Moon goddess and twin sister of Apollo).

At a subsequent NASA "town hall," Bridenstine maintained that the SLS remained the "best option" to get to the Moon, but he charged NASA with accelerating the SLS's testing schedule to avoid further slips to the launch deadline. Besides adding extra work shifts, proposals included horizontal integration of the core stage and skipping the all-up "Green Run" test firing of the four RS-25 main engines. The Green Run survives, but NASA continues its time-saving drive for the SLS.

RISKY BUSINESS

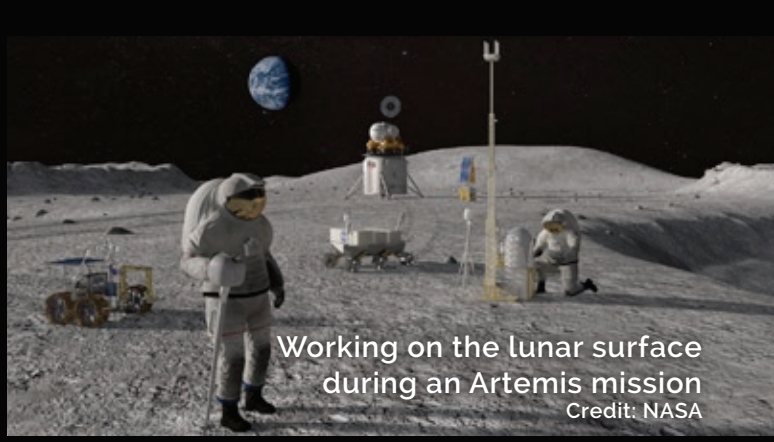
Reactions to the administration's accelerated lunar landing plans were mixed and, in some cases, tempered by earlier presidential calls for bold initiatives. Key members of Congress were generally supportive—especially those with NASA centers or manufacturers in their district—if the Space Launch System survived intact. At the same time, some partisan voices questioned the timing and cost of the fast-tracked lunar program.

Bridenstine (a former member of Congress) recognized the multiple risks facing the initiative, acknowledging "there's a lot of schedule risk, programmatic risk, and technical risk . . . so it's not easy, but it's doable. I think the bigger risk, that has to be retired earlier, is the political risk. How do we get the money?" To that end, Bridenstine pledged to "make sure that, as much as possible, we're driving bipartisan, apolitical decisions and processes into the matrix."

Meeting the 2024 Moon landing deadline will demand swift decisions and action. "Analysis paralysis" and endless PowerPoint presentations must be replaced by bending metal and soon. NASA has already awarded Maxar Technologies a contract to accelerate the development and testing of the Gateway's Power and Propulsion Element via public-private partnership. Blue Origin is the likely launch provider since it is a partner on the project. NASA also tapped Northrop Grumman to build a mini-habitation module—dubbed the Habitation and Logistics Outpost (HALO)—after reckoning it was the only company able to meet the accelerated timeline.

NASA fleshed out its latest lunar landing architecture in late April admitting that "it is not easy and it is not risk-free." The blueprint included an initial minimal Gateway and three launches of the SLS, starting with the uncrewed test flight (Artemis 1) in late 2020 or "sometime in 2021." The year 2022 is slated to send astronauts

Blue Origin's crewed Blue Moon lander
Credit: Blue Origin



Working on the lunar surface during an Artemis mission
Credit: NASA

circumnavigating the Moon aboard the SLS-launched Orion spacecraft (Artemis 2) while the Gateway's PPE is boosted there on a commercial rocket. The Moon-circling station would achieve "minimal habitation capability" in 2023 with the commercial sendoff of the HALO module. The third launch of the SLS and Orion (Artemis 3) in 2024 would mark the initial lunar landing. In NASA's reference architecture, lunar lander elements would fly on commercial launchers. Annual crewed landings would follow and transition to reusable lander elements over time. In all, NASA sees two phases of lunar exploration: the first marked by speed, and the second by sustainability and affordability.

NASA issued a final version of human lunar lander requirements in late September incorporating industry comments. These latest specifications allow the mission profile to bypass the Gateway (for early lunar sorties), eliminate the requirement for lander reusability, and allow companies to propose the SLS to launch their landers. Notably, the agency also weighted "Total Evaluated Price" higher than "Management Approach" as a criterion for evaluating landing system proposals.

ARTEMIS OR HIT?

Even as the commercial sector steps up to the 2024 lunar challenge, NASA is walking a delicate tightrope to build political support and finance the initiative while juggling competing internal interests. In late spring, the Trump administration and NASA pledged a 1.9 billion dollar "down payment" for NASA's 2020 budget, earmarked for lunar landing efforts. The budget surge would be offset by 320 million dollars in cuts to the Gateway downsized to an initial minimal configuration.

"This . . . gets us out of the gate in a very strong fashion and sets us up for success in the future," NASA's chief explained. Most of the funds—approximately one billion dollars—would go towards the development of the industry-led "integrated commercial lunar lander," but a hefty 650 million dollars would be reserved for the SLS and Orion "to make sure they stay on track." Some estimates place Artemis's total cost at 20 to 30 billion dollars though Bridenstine indicated commercial and international partners could partially offset these sums.

Unfortunately, Congress's byzantine appropriations process has shortchanged the administration's budget request for a lunar lander. House appropriators zeroed any funding while the Senate budgeted 744 million dollars, well short of the amount NASA said it needed to keep Artemis on track. By November, Congress still had not agreed on a budget resolution, instead passing a stopgap "Continuing Resolution," which does not allow new program starts. The agency admitted that delayed and chronic underfunding could "affect the number of proposals that can be [selected]" stressing that the "budget is key and central to our acquisition strategy" for a lander. Facing budget uncertainty, Bridenstine has cited several creative ways to fund a human landing system. The U.S. space agency awarded 45 million dollars to 11 companies, including Blue Origin and Lockheed Martin, to conduct studies and produce prototypes of human-scale lunar landers and transfer vehicles. Bridenstine also hinted that funds from the agency's Commercial Lunar Payload Services (CLPS) initiative could support lander development.

The NASA administrator has taken pains to reassure members of Congress and NASA stakeholders that existing programs—including sacred cows like the SLS—would not be axed in NASA's drive to the Moon. To skeptical congressmen, the administrator argued that the rapid pace reduced political risk by minimizing partisan transitions. He also made an argument that would have been familiar 50 years ago. "It's not by accident that so many countries around the world . . . are going to the Moon," he said. "Not all of them are going . . . just to collect rocks. It's a strategic imperative that the United States have a presence there as well."

In Greek mythology, Artemis had a direct lunar connection, and in some versions of the myth symbolized feminine power and independence. Such qualities are fitting for a program that aims to land the first woman and next man on the Moon through public-private partnerships. Five decades after the first Moon landing, space entrepreneurs and companies are increasingly driving America's path to deep space. No hypothetical breakthroughs are needed. Manufacturing efficiencies and innovative strategies, such as reusability, together with experience, skill, and engineering competence can hasten and sustain the journey. In these areas, commercial players are in the vanguard of public-private initiatives. That model, not yet fully exploited, is the surest, quickest, and most economical path to the Moon and beyond. It will be vital to exploit these initiatives to the fullest since both the deadline and funding of Project Artemis are short.

LUNAR LANDER CONTENDERS

A "NATIONAL TEAM"

Building a lunar lander will set the pace for fresh footprints on the Moon and NASA has wasted no time in soliciting proposals. In response, retail and rocket magnate Jeff Bezos announced that his company, Blue Origin, was teaming with Lockheed Martin, Northrop Grumman, and Draper Labs to develop a human-rated lander. "This is a national team for a national priority," declared Bezos. Under the arrangement, Blue Origin will provide overall project management and build the Descent Element based on the company's Blue Moon lander, with Lockheed Martin responsible for a reusable Ascent Element and Northrop Grumman the Transfer Element. Draper will lead descent guidance and flight avionics.

The "cargo" version of Blue Moon can deliver four tons (3.6 mT) to the lunar surface, while a "stretch" variant can land at least 7.2 tons (6.5 mT) balanced on the cryogenic BE-7 hydrolox engine. This "larger variant of Blue Moon has been designed to land an ascent vehicle," the company has pledged. The BE-7 engine is highly throttleable and can thrust up to 10,000 pounds-force (44 kiloNewtons). Filled with propellant, the cargo variant of Blue Moon weighs "33,000 pounds" (15 mT) which dwindles to "less than 7,000 pounds" (3.2 mT) when empty, allowing the craft to burn into the Gateway's orbit and descend to the surface with margin to spare. Stretch Blue Moon has a roughly similar performance. On the surface, the craft can survive the long lunar night by boiling off liquid hydrogen to chill oxidizer tanks and supply fuel cells generating electricity.

Lockheed Martin's contribution, the Ascent Element, will leverage Orion systems and possibly repurpose the shuttle-era Orbital Maneuvering System (OMS) as the main propulsion unit. Northrup Grumman will base the Transfer Element on its Cygnus cargo carrier, propelled by the BE-7 engine to shuttle between the Gateway and low-lunar orbit. Overall, the architecture will "fully exploit" the capabilities of Blue Origin's New Glenn rocket, with each element launched separately. The three elements will aggregate, rendezvous, and dock at the Gateway.

In August 2019, Bezos sold nearly one million shares, or 1.8 billion dollars worth, of Amazon stock to fund Blue Origin as the company gears up for Project Artemis. While the "national team" proposal offsets costs to the agency and mirrors NASA's reference architecture for human landing systems, it faces technical and programmatic risks including development of a new hydrolox engine and numerous launches and dockings.

BOEING'S BID

The lunar lander proposed by Boeing takes a markedly different approach starting with a two-stage design that forgoes a Transfer Element altogether. Instead of using separate commercial launch vehicles for each element, an integrated lander composed of ascent and descent elements will ride uphill on a Block 1B SLS. The lander will incorporate innovations in "engines, composites, and automated landing and rendezvous systems" with "key technologies" based on Boeing's CST-100 Starliner spacecraft.

Boeing's lunar lander stage boosts toward the Moon. Credit: NASA

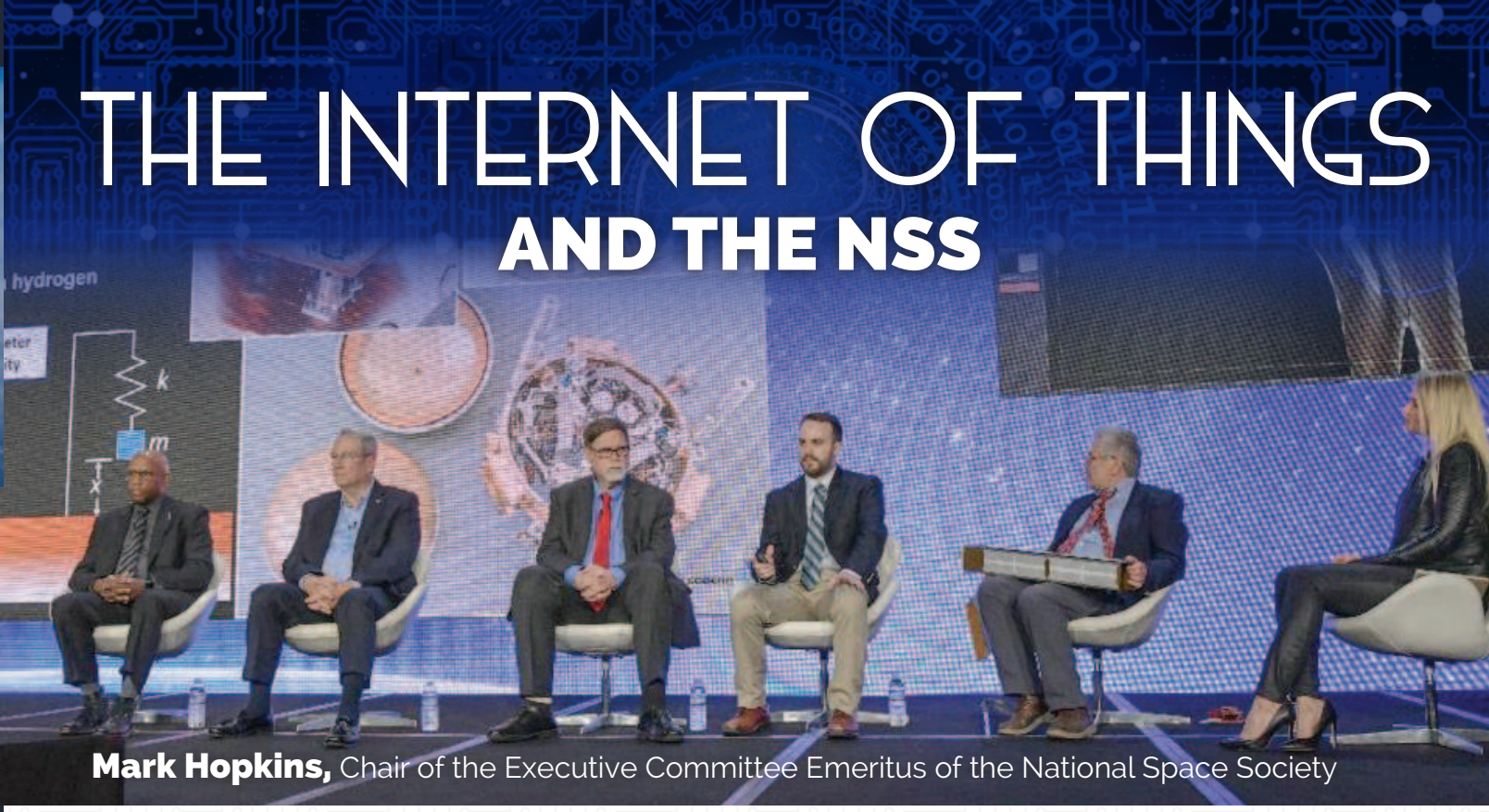
The aerospace giant has recruited engine maker Aerojet Rocketdyne and commercial lander startup Intuitive Machines for propulsion knowhow. Houston-based Intuitive Machines was tapped to "build, test, and deliver . . . main stage and reaction control (RCS) engines" with cryogenic methalox propellant used in "all elements." The initial, or baseline, lander will rely on solar panels for power generation. A spokesperson confirmed to *Ad Astra* that Intuitive Machines is developing "cryogenic tanks, precision landing, and hazard avoidance software" for the lander. The company has also test-fired a methalox engine producing 3,500 pounds-force (15.6 kiloNewtons) of thrust.

Boeing, which is also building SLS's core stage, contends that its "Fewest Steps to the Moon" proposal "minimizes mission complexity" by reducing the number of launches and other "mission critical events," such as rendezvous and docking. It is true that internal NASA studies have shown that "two-element architectures can result in lower architecture mass and reduced operations complexity" than a three-element design.

At the same time, there are logistical, schedule, and cost risks to this strategy. Flying the Block 1B configuration of the much-delayed rocket will be a pacing item for the Artemis 3 Moon landing, with two SLS launches needed per sortie—one each for Orion and the integrated lunar lander. To meet that goal, SLS production must ramp up dramatically and avoid production and logistical bottlenecks. However, NASA chief Jim Bridenstine observed that "Given our current rate of production, we will have three SLSs available, and [the] third one would be for Artemis 3 . . . Adding an additional SLS into the mix? I'm not confident that could happen."

As for price tag, NASA has ordered companies proposing the SLS as a lander transport to calculate the cost for a cargo version of SLS as part of their proposal. Development and operational cost estimates for SLS vary, but the Office of Management and Budget (OMB) pegged the rate at "over 2 billion dollars per launch . . . once development is complete" while NASA's Inspector General projected "at least 876 million dollars" to build a second rocket in a given year. Such ten-figure sums are prone to sticker shock and might undermine the Artemis program's sustainability.

THE INTERNET OF THINGS AND THE NSS



Mark Hopkins, Chair of the Executive Committee Emeritus of the National Space Society

Chantelle Baier, the Creative Arts Director of the National Space Society, organized a panel representing the organization at the Internet of Things (IoT) conference last May. The unexpected result of this decision was a demonstration of just how powerful the NSS's message has become in recent years.

The IoT conference had over 12,000 attendees, 150 sessions, and 300 exhibitors. The agenda covered subjects like industrial IoT, smart homes, smart cities, security, edge computing, smart buildings and construction, agriculture, AI, healthcare, energy, utilities, and transportation.

NSS leaders were featured on one of a very few plenary panels and had an excellent speaking slot within the agenda. Included were Karlton Johnson, Chairman of the NSS Board of Governors; Bruce Pittman, Senior Operating Officer; and Mark Hopkins, Chair of the Executive Committee Emeritus; with Baier as the moderator. Johnson predicted that the internet of things will be important as we expand to the Moon and Mars, and that internet security will be a significant issue. Pittman stressed that we will learn much about sustainability in space and these lessons can help us on Earth. Hopkins addressed the issue of why space is important, as space resources may allow us to move beyond the resource constraints of Earth.

During the conference, members of the team were approached by attendees who congratulated them for the ideas they had presented. One of the people in the audience for the panel was Alan Boehme, the Chief Technical Officer of Procter and Gamble (P&G), one of the largest consumer companies in the world with over 80 billion dollars in annual revenue. P&G owns many iconic brands, including Tide, Crest, Gillette, Pampers, Head and Shoulders, Dawn, Ivory, Vicks, Old Spice, Charmin, Duracell, Clorox, Johnson and Johnson, Walmart, Reilly Auto Parts, Kmart, Woolite, Luvs, and Tupperware. Boehme wants to use space to help sell P&G products, which can help to promote the NSS's vision.

Following the IoT conference, Baier obtained a 15,000 dollar sponsorship from P&G and convinced Boehme to send a personal video supporting the 2019 Space Settlement Summit. With an assist from Boehme, she was able to speak at the Web Summit in Lisbon, Portugal, which had more than 70,000 attendees.

The NSS's vision of space settlement and the use of space resources for the dramatic betterment of humanity has moved from something once considered improbable to something within reach. It is the NSS's job to take full advantage of this fact and lead humanity into a hopeful and prosperous future.

A video of the panel discussion is available at go.nss.org/iot-panel.

ISDC 2020

CONTINUING THE JOURNEY

Ad Astra staff

Marc Rayman in the High Bay at NASA's Jet Propulsion Laboratory
Credit: NASA

Peggy Whitson
Credit: NASA

The 2020 International Space Development Conference® is just around the corner, and organizers have been working hard to ensure a great event this year. This year's conference chair Anthony Paustian and Conference Committee Chair Dave Dressler have some great speakers lined up. "At the beginning of each episode of *Star Trek*, Captain Kirk would close the opening titles with, 'To boldly go where no man has gone before," Paustian explains. "While we did send men to the Moon a few years after *Star Trek's* premiere in 1966, going further has eluded us. ISDC 2020 will continue the journey and explore how we can once again send people back to the Moon in order to reach Mars and beyond."

Notable speakers include Peggy Whitson, a former astronaut and the first female commander of the International Space Station. She was the oldest woman to perform an EVA and also holds the record for the most cumulative days in space for any NASA astronaut at 534 days.

Phil Plait of "Bad Astronomer" fame will speak on a variety of cosmic topics. Steve Jurvetson, a billionaire investor in NewSpace who provided a much-needed financial boost to SpaceX in 2008, and who has steered large investments in Planet Labs and other commercial space ventures, will speak. Jurvetson has also accumulated the largest known private collection of space-age paraphernalia. Prominent oceanographic explorer David Gallo, the Director of Special Projects at the Woods Hole Oceanographic Institution, will speak on the connections between deep-sea exploration and space settlement.

Finally, U.S. Air Force Lt. General (Ret.) Steven Kwast, an ISDC favorite, will present on leadership for our "next giant leap."

Members of the Austrian royal family will present the *Flame of Peace Award* at ISDC, which is awarded by the Austria-based Association for the Promotion of Peace. Founded in 2008, the award has been presented to prominent individuals who promote activities that support global peace. In 2020, the award recognizes the importance of peaceful uses of space and two will be presented at the ISDC. The first recipient will be NSS Executive Committee member Anita Gale for her work with the International Space Settlement Design Competition. The second award will be accepted by Geoffrey Notkin, president of the NSS, on behalf of the organization, which is being recognized for internationally promoting the commercialization and settlement of space.

A top-notch group from NASA's Jet Propulsion Laboratory and associated institutions will be on hand to discuss the robotic exploration of the solar system. This includes Scott Bolton from the Southwest Research Institute discussing the Juno probe to Jupiter, Jim Bell from Arizona State University holding forth on the Mars 2020 rover, and Marc Rayman from NASA's Jet Propulsion Laboratory speaking about the DAWN mission to the asteroids Ceres and Vesta, one of the first deep space probes to utilize an ion drive.

New tracks are being added this year, which include:

- *Seasteading for NewSpace*, chaired by Carly Jackson, which outlines plans for oceanic settlement in terms of self-sufficiency, independence, governance, and climate change mitigation.
- *Space Health*, chaired by Bill Gardiner, which looks at the physiological aspects of long-term space travel and permanently living off-Earth.
- *Science Fiction to Fact*, chaired by conference chair Anthony Paustian, which discusses how fiction is becoming fact in the rapidly advancing realm of space development and settlement.

Other presentation tracks which previous attendees have long enjoyed will return for 2020, and include *Lunar Exploration and Development*, *Mars Exploration*, *Living in Space*, *Space Solar Power*, *Space Elevators*, *Space Business*, *Space Policy*, *Space Transportation*, *Interstellar*, the *Launchpad* short talks series, and *Space Settlement*.

"For anyone who has not yet attended an ISDC, please consider joining us in Frisco, Texas on May 28th for a continuously advancing, enthusiast focused festival of space exploration and development," said Dressler. "For returning attendees, the ISDC team thanks you for your continuing support of the NSS and our biggest event. We look forward to gathering with you again, and continuing the journey to the Moon, Mars, and beyond."

Phil Plait, the "Bad Astronomer."
Credit: Phil Plait

ASTRO

TESTING NEW SPACE TECHNOLOGIES IN THE ARCTIC

NAUT

Testing the Astronaut Smart Glove with a drone at the Houghton Mars Program base on Devon Island.
Credit: HMP/Pascal Lee

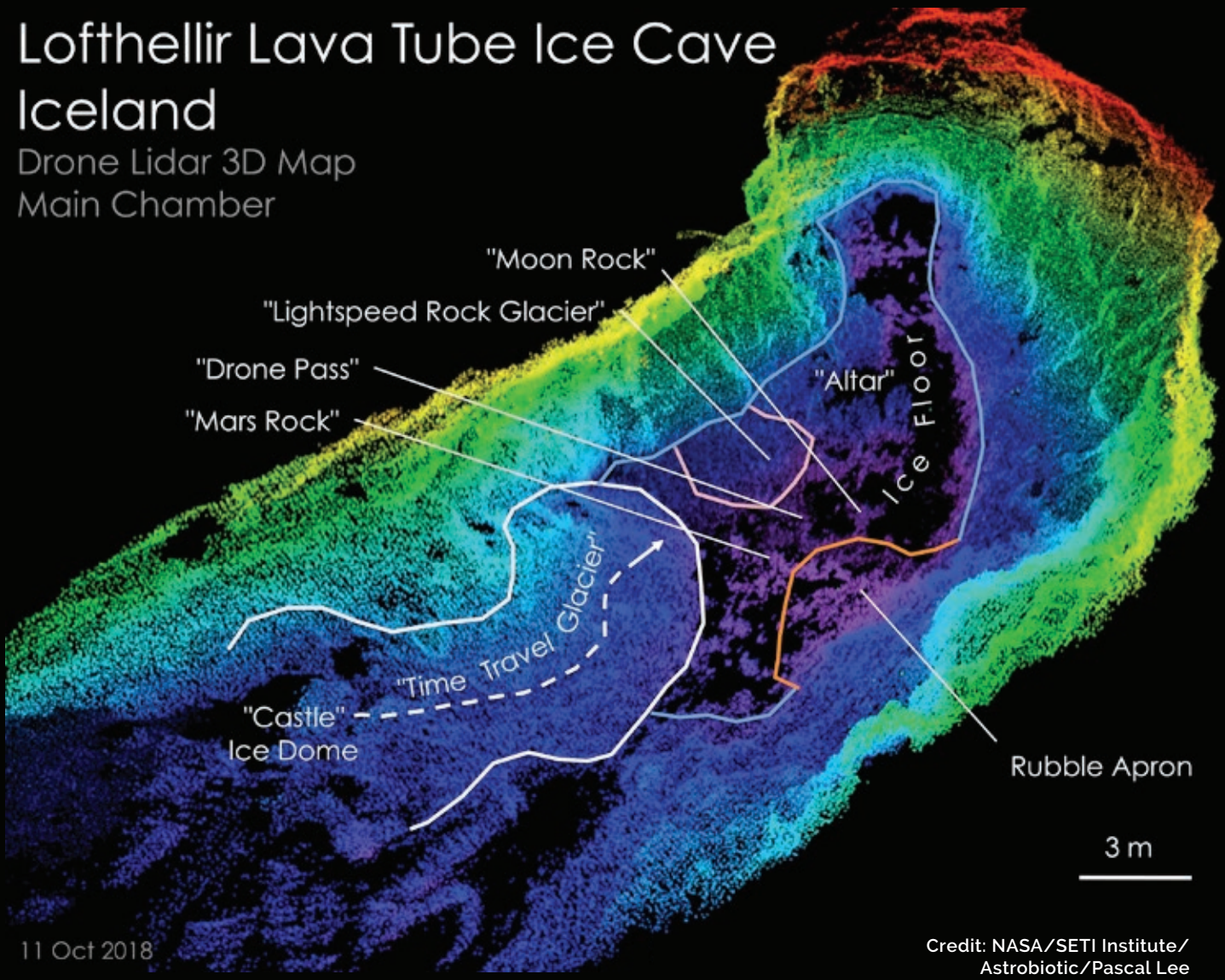
TOUGH

Melissa Silva

Pascal Lee tests the operation of an aerial drone at the Houghton Mars Program base in the high arctic.
Credit: The Mars Institute

Drones, more formally known as Unmanned Aerial Vehicles (UAVs), have versatile applications in today's world, whether for use in military combat situations, by hobbyists, or Amazon's product deliveries. They have deep roots in military history. The first operational UAVs were incendiary balloons launched by Austrian imperial forces against Venice during the city's 1849 siege, a use that quickly backfired when the winds shifted, and several balloons rained back down on the Austrians. This was followed by an assortment of pilotless aircraft and remote-controlled weapons that were developed for combat during World War I and II, with the term drone coming into use some time in between those two conflicts. Much later, the radio-controlled model plane boom of the 1960s fascinated hobbyists. Today, drones are getting smarter, lighter, and increasingly inexpensive. Most are multi-rotored copters, and the list of what they can achieve continues to grow as they become more widely utilized in military applications, video and film production, and even in scientific research.

Planetary scientist Dr. Pascal Lee, co-founder and chairman of the Mars Institute and Principal Investigator of NASA's Haughton-Mars Project (HMP), is developing drone technology that can be used to explore environments on the Moon and Mars, and in particular the inside of caves. Many scientists, including Lee, suspect that some of these formations are likely to harbor water ice, and in the case of Mars, possibly biosignatures, or even extant life. "Exploring caves on the Moon might give you access to non-polar water and will prepare you for exploring caves on Mars," says Lee, noting that caves are sheltered environments that are



Credit: NASA/SETI Institute/ Astrobiotic/Pascal Lee

Operations at the Lofthellir lave tube.
Credit: Pascal Lee

in important ways less hostile than conditions at the surface, and would be useful to astronauts on future missions.

"Inside a cave, you're sheltered from ionizing radiation from galactic cosmic rays and the sun," he continues. "You're protected from micrometeorite bombardment and drastic day-night temperature variations. You're also somewhat protected from dust and the wind. In any case, you're dealing with an environment that's very different from the surface. It's almost like exploring two planets on one, because you've got the surface and you've got the cave, and those are two radically different settings."

Of special interest are "candidate pits" in the Moon's high latitude regions, which have escaped detection by researchers using automatic detection software. "I emphasize 'candidate' because we can't tell for sure yet," says Lee. "Most of the confirmed pits and caves scientists have discovered on the Moon are at low latitudes, between about 60 degrees north and 60 degrees south. That's a bias caused by the software used to automatically search for them. The software relies on the fact that sunlight shines down into the bottom of the pit, say the skylight of the lava tube, and as the sun moves across the sky over the Moon, the portion of the floor of the pit that's lit changes over time. By detecting these changes, the software decides automatically if there's a pit or a cave there or not." But at high latitudes, this approach no longer works.

Beyond about 70 degrees latitude, sunlight would never reach the bottom of a pit, so the search for pits would take a more hands-on approach. This prompted Lee to sift through hundreds of images of the lunar polar and circumpolar region taken by NASA's Lunar Reconnaissance Orbiter. To his delight, he found a few candidate pits on the floor of Philolaus Crater, a 43-mile (70-kilometer)-wide impact structure on the near side of the Moon at 72 degrees latitude.

"What makes high latitudes pits so interesting is that sunlight no longer shines into them. The pits are in perpetual darkness, and without solar illumination, the rocks on the floor of the cave are never warmed up; therefore, these rocks never radiate any heat into the rest of the cave. We'd have lunar caves that are super cold, as cold as the Permanently Shadowed Regions (PSRs) at the Moon's poles. Therefore, these caves, if

Pascal Lee and his trusted companion, Apollo.
Credit: The Mars Institute

they're confirmed, could cold-trap ice, just like the PSRs do."

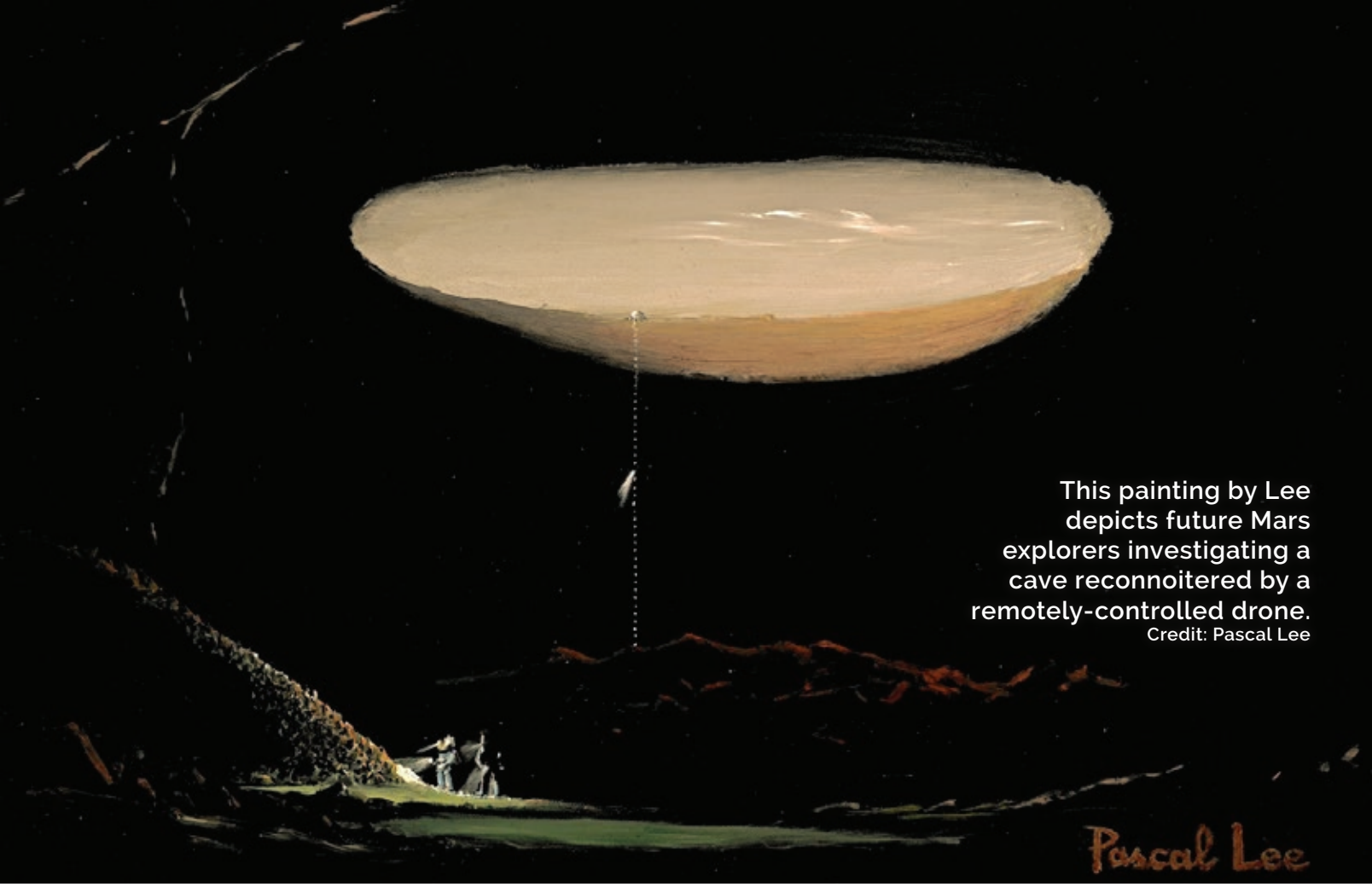
"We now know that there is water ice in the polar regions of the Moon," he continues, "and this ice has probably been accumulating over time." The ice is believed to come mostly from above—molecules of water bouncing across the lunar surface originating from any part of the Moon; once they stray into the PSRs, it's so cold—close to the temperature of liquid nitrogen—they then stick there. So, one molecule at a time, you'd build up an ice deposit. The same process could build up ice inside a high latitude pit, which means we might have additional options for finding water on the Moon."

Lee's ultimate goal is to explore these regions first with robotic scouts, then with astronauts. Robotic systems he and his teammates are considering include touchless options such as gas-thrustered drones, and all-terrain soft-touch options such as JPL's GlobeTrotter concept of an inflatable hopper. Both options could work well on the Moon or Mars. In October 2018, Lee and teammates from Astrobotic Technology successfully mapped the Lofthellir Lava Tube Ice Cave in Iceland using an autonomous LiDAR-equipped drone. "Drones are nimble, quick, and touchless, and could fly in and out of caves to warm up, recharge, and send data back before reentering the caves to map them further. But they might stir up dust," Lee says. With GlobeTrotter, "you would instead bounce along the surface in a spacecraft wrapped in airbags, drop down into a lava tube through its skylight, come to rest, collect data, then fly back out via a now known path using small thrusters, and on you go. You'd kick up dust only on the way out."

Astronauts could also use drones in real-time. Lee's latest project, the "Astronaut Smart Glove," is a collaborative effort between the SETI Institute, the Mars Institute, NASA Ames Research Center, Collins Aerospace, and Ntention, the company that first developed a glove for single-handed drone operation.

"Ntention's glove captures 'human intent' and allows people to fly commercial drones intuitively. When I saw a demo of this tech earlier this year, I was blown away by

Close-up of the drone-operating "Astronaut Smart Glove."
Credit: The Mars Institute



This painting by Lee depicts future Mars explorers investigating a cave reconnoitered by a remotely-controlled drone.
Credit: Pascal Lee

the implications this could have for a EVAs (extra vehicular activities). We decided to work together to adapt the capability to an astronaut spacesuit glove and took it to the Arctic for a field test this summer," Lee says. "As the tech was already mature, it worked really well. The tech had the benefit of being already developed for other applications. Incidentally, that's what you want for things you fly in space. People sometimes think that when you fly technology in space, it's cutting-edge. But you really don't want cutting-edge when it comes to humans in space; you want reliable, robust, proven and safe technology that has many, many operational hours behind it."

Drones are promising robotic assistants for human explorers, including in real-time on EVAs. They could be used for search and rescue, sampling, scouting, fetching, and many other "on the fly" operations. On Mars, drones can be equipped with aseptic (sterilized) tools to collect astrobiological samples, and thus avoid any direct contact and contamination risk between astronauts and an astrobiological target.

"This is where human intervention becomes really interesting. Let's say you are at the edge of a canyon and you see a [wet] gully on the other side of the canyon. You want to collect a sample, but you can't get there without violating planetary protection directives. You can program a drone to pick up some suboptimal sample autonomously, or you can do this very deliberately, with your scientist-astronaut brain operating the drone to pinpoint exactly the sample that you really want."

That's where the Astronaut Smart Glove comes in. It allows the user to control a drone single-handedly with simple finger and hand gestures. "It's controlling the drone by arm-waving," muses Lee. "We think that this technology will be useful for any type of action an astronaut takes while exploring the Moon or Mars that requires dexterity. Astronaut suits are notoriously cumbersome and become even more so when pressurized, so operating a drone by using conventional interfaces with joysticks would not be practical. The Astronaut Smart Glove frees up one of your hands, has an intuitive interface, and uses an augmented reality head-up display. It also takes pressurized spacesuit rigidity into account and has adjustable finger and hand motion sensitivity," he added.

Lee's team's successful first field test of the Astronaut Smart Glove at the HMP base on Devon Island in the Arctic will be followed up by further tests. "We want to continue to test the glove in a higher-fidelity suit where we are actually pressurized, to see what level of effort that's going to take for the astronaut's hand to move his or her fingers and hand to operate a drone, or any other robot for that matter, for instance a robotic arm" says Lee.

Seeing a spacesuited figure flying a drone by waving their arm in the Mars or Tatooine-like landscape of Devon Island evokes an almost child-like whimsy. Lee recalls a quote from British science fiction writer Arthur C. Clarke that sums it up nicely: "Any sufficiently advanced technology is indistinguishable from magic."

AN INSPIR

North American Rockwell's wooden shuttle mockup when new.
Credit: Aerospace Legacy Foundation

THAT NEVER FLEW

The Wooden Space Shuttle

Francis French

Space fans still debate which space shuttle came first. Some would say this distinction belongs to *Columbia*, the first shuttle to fly. Others might say *Enterprise*, which never flew in space, but was built before *Columbia* to test how the shuttle could land on a runway. Yet there was another shuttle built before these, one that never left the ground, and was made of wood. It is still around, and while its journey has not been as glorious, it has still been remarkable in its twists and turns. It also makes us think about how artifacts from history should be preserved and protected.

In the fall of 1972, North American Rockwell was given one of the biggest aerospace contracts in history. The company—located in Downey, California—already had experience in building space vehicles as they had recently built the Apollo Command and Service Modules, and the second stage of the mighty Saturn V rocket that sent humans to the Moon. As the builders of the X-15 rocket plane, they were also the only contractor to have built a winged vehicle capable of returning from the fringes of space.

But building a much larger crewed spacecraft—one the size of a commercial passenger airplane—was going to be a significant step up from building Apollo spacecraft. To test the size

of the hardware needed for the shuttle, and how shuttles could be lifted and moved, the company decided to build a full-size prototype. Blueprints and artists' impressions were replaced by a physical mockup that allowed people to experience a life-sized shuttle in person.

The first time I saw it, around the turn of the century, the shuttles were still flying in space, but this one had been forgotten. It sat in a pitch-black room among the abandoned hangars of the long-closed North American plant. I was there as part of a volunteer team to rescue what was left of the documents that the engineers had left behind. While bulldozers destroyed the other end of the building, we worked through dusty office spaces by flashlight, rescuing old blueprints from aging file cabinets.

Exploring an entire space shuttle with only the small circle of a flashlight beam is rather eerie; however, for me it was fascinating. I worked my way along a wing, finding the nose, and then some stairs that took me through the spacecraft hatch and into the shuttle's lower deck. As I climbed into the cockpit, which was filled with switches to simulate the feel of the early shuttle designs, I gained an appreciation for what the contractors had built. This mockup was immense. I had seen space shuttles many times when readied for flight, but climbing around inside this one felt less futuristic and more like archaeology.

When it was first built, and was still gleaming and new, the mockup served another purpose: impressing visiting VIPs such as the senators and congressmen who approved the funding for the shuttle program. Allowing them to see a shuttle up close, and climb inside and sit in the commander's couch, would be much more persuasive than showing them a series of slides in a conference room. Apparently, it did the trick, as over 20 years six shuttles were built at the plant. President Reagan visited in 1982, and the following year Queen Elizabeth and Prince Philip toured the shuttle mockup, which became a point of national pride at the sprawling aerospace plant.

By the late 1990s, however, North American Rockwell was in trouble. With no large, new projects such as Apollo or the space shuttle to work on, the facility was closed. The enormous shuttle mockup that sat within the plant was too large to be moved easily, and with no alternate home or desire to demolish it, the wooden shuttle was donated to the city and sat for years forgotten by all but a few dedicated historians.

City executives hoped that the public would remember Downey's contributions to the space program, but there was little money to refurbish and house the aging wooden relic. In the meantime, plans were proposed for the enormous acreage of the old plant. Parts were turned into a hospital and a shopping center, while the hangars, unusual because of their enormous size, were converted for use by movie studios. Scenes from the *Iron Man*, *Spiderman*, *Terminator*, and *Indiana Jones* franchises were filmed there. By 2012, the studio had closed down; computer technology, which owed a great deal to the space program, had advanced to the point where enormous hangars were no longer necessary to film movie scenes. I visited that year and could see only a wasteland of twisted girders—the hangars had been torn down.

Despite having little money to spend, two local efforts were underway to preserve and commemorate this place where America's spaceships had been designed and manufactured. One was the Columbia Memorial Space Center, a museum built on one corner of the old plant, which opened in 2009. The museum's Challenger Learning Center and other exhibitions allows families to learn about the past and present of aerospace, and children are encouraged to imagine the future of spaceflight.

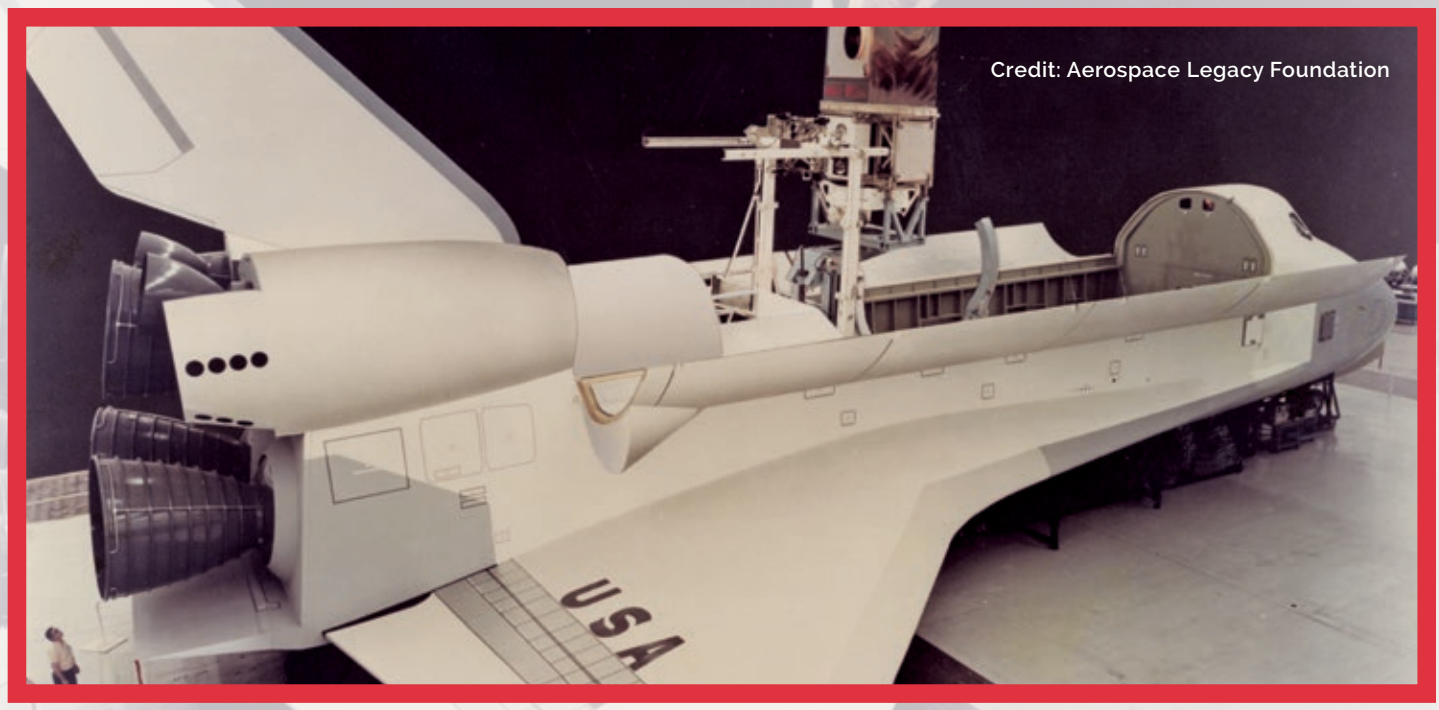
The other effort is the work of one person: Jerry Blackburn, who worked at the plant for 40 years as a project manager, and didn't leave when it closed. He led the effort to save abandoned documents before buildings were torn down. Using a small building on-site, he stored all of the irreplaceable pieces of history that he could. When the inevitable day came that the rest of the plant was torn down, he and the site developer already had the wooden shuttle disassembled and stored. From the space-loving mayor to a cadre of volunteers, Jerry had the connections and enthusiasm to save the shuttle.

"The Downey space shuttle mockup became an icon for the Rockwell-Boeing company, the city, and the community of men and women who worked at the site," Blackburn explains. "It was host to a cadre of VIP visitors, guests, and students. It was built to be an engineering aid to help visualize the complex designs of equipment and hardware that would make it successful. It was also seen as a way to market the future of commercial aerospace by showing payload clients the possibilities this vehicle could have for space applications. It overwhelms you with its size."

"Because it was full-scale, the vertical stabilizer had to have 20 feet removed to fit into the display room at the site. One of the wings was also removed. They were placed in storage, and eventually scrapped," he continues. "The abbreviated version still had enormous impact on visitors, who would stand next to it in awe. Because of its friendly access, it was our best advertisement for the American space program. But its impressive size has also been its greatest challenge in finding a new home."

It could have been easy to find a new home for it, as full-sized space shuttles were in great demand around 2011. The last shuttle mission had returned from orbit that year and with NASA offering up hardware to museums around the country, there was frantic competition to obtain one. The California Science Center, only 10 miles from the Columbia Memorial Space Center, successfully won the shuttle *Endeavour*, the last to be manufactured in Downey. Other museums around the country, unable to obtain flight hardware, made inquiries to see if the city's mockup was available, but Downey had its own plans for it.

The city created an ambitious project to refurbish and create a permanent home for its wooden shuttle. As part of the process, the mockup was checked for damage. It was beginning to show its age, with buckling wood and plastic



Credit: Aerospace Legacy Foundation

components beginning to crack and detach. However, the decay was deemed repairable with sufficient restoration effort. As part of the efforts to raise awareness, the shuttle was also finally given a name: *Inspiration*.

By 2013, the mockup had made a second move, this time to a large tent outside of the Columbia Memorial Space Center. On select days of the week, the public could tour it. When I visited, I could see this was not ideal storage; with no floor, rainwater could flow under the shuttle unchecked, and moisture was not helping its preservation. Three million dollars were subsequently raised to build a community center, one that would protect the mockup from the elements while also allowing access to the public.

Yet, as often happens in city politics, people change their minds. Concerned about the potential cost, the city council decided to disassemble the shuttle again, and reassemble it when a manager was hired to oversee the project. The tent had been rented and needed to be returned. The lot the shuttle sat on was now needed for a new development. After almost two years in the tent, the shuttle was trucked in pieces to a city storage facility, where it sits outside, covered in protective tarpaulins. It remains there to this day.

Hindsight is everything. For a guaranteed future, the city could have sold or given *Inspiration* to one of the many interested parties back in 2011. Its future is currently undecided, but Jerry Blackburn has not given up hope that the city will do something positive with the shuttle. In fact, he's excited about new possibilities.

"The long term storage of *Inspiration* has been a calculated risk," he explains. "The decision to separate the exhibit into smaller sections and contain them in environmental storage bags may have been acceptable if they were stored inside; but the decision to store them in a public works yard outside has put the exhibit at risk. Wood and plastic are not designed to be outside. Inspection and processing . . . need to begin immediately. With the opportunity of new state funding available, this may now be possible."

"There is a wonderful potential for *Inspiration* to become an interactive learning exhibit at the Columbia Memorial Space Center," Blackburn continues. "The static and passive displays of the real orbiters around the country have left the public with a desire to see more. There is money earmarked at the state level that can be used to give the shuttle a fourth and final move to a permanent home. There is land designated right next to the center for this new building."

It's an attractive idea. The Museum of Flight in Seattle, for example, has taken full advantage of having a shuttle trainer used by astronauts in their collection. Unlike flown spacecraft, visitors can actually get inside. For about a dollar a minute on a guided tour, in addition to the general museum entry fee, visitors can get a sense of what it is like to be inside a large spacecraft, while other visitors remain outside and marvel at the size of the vehicle.

Ben Dickow, president of the Columbia Memorial Space Center, was hired long after *Inspiration* was placed into storage. He has inherited a challenge, and an opportunity.

"Restoring and displaying *Inspiration* is at the center of our planning for the new addition," he explains. "While it's too early in the process to have specific details, our desire is to make the mock-up an engaging immersive experience for our visitors. The mock-up is a vital part of the engineering story of the shuttle and speaks to the educational messages we try to promote through our exhibits and programs. It, and all of the people, especially in Downey, who built the space shuttles, should be celebrated in the experience. That will take resources, however. The funds from the state are a wonderfully generous start, but it will take a lot more to realize our vision."

Francis French can be contacted via his website, www.francisfrench.com.

DANGEROUS DUST

John Gould

HAZARDS FACING FUTURE SETTLERS ON OTHER WORLDS

"WE'D LIKE TO CHANGE OUR CALL SIGNS TO PIG-PEN 1 AND PIG-PEN 2."
CHARLIE DUKE, APOLLO 16, REFERRING TO HIMSELF AND MISSION COMMANDER JOHN YOUNG

Credit: NASA/JPL-Caltech

The recent mandate to return humans to the Moon and establish a base there comes with a number of problems that have yet to be solved. Among these is the development of an orbital gateway, a new lunar lander, and a lunar base, as well as issues of life support and additional destination hardware. Critical to the function of a number of these systems, especially Environmental Control and Life Support Systems (ECLSS), will be the ability to withstand interference from abrasive lunar dust.

Lunar dust, the finest component of lunar regolith, is unlike any substance on Earth except for simulants expertly crafted by researchers at NASA and several universities. Real lunar dust is the result of volcanic activity on the Moon followed by billions of years of pulverization from meteor and micrometeorite impacts. With no air or water to weather the dust, the tiny particles of rock are sharp, dry, and able to hold an electrostatic charge that can cause them to hover up to 33 feet (10 meters) above the surface near the Moon's terminator. These characteristics cause lunar dust to adhere to almost every surface it touches, making documents unreadable, contaminating scientific experiments, damaging pressure seals, scratching glass and metal, and, most concerningly, coming into direct contact with astronauts' skin, eyes, and lung tissue.

The first time lunar dust interfered with a crewed mission was during Apollo 11, when it was discovered after the mission that the dust had prevented the sample-return boxes from holding an airtight seal. These seals, constructed of "knife-edge indium," would not maintain a seal on future missions either. Apollo 12 had even more problems with lunar dust during the mission when Pete Conrad and Alan Bean had trouble keeping experiments on the lunar surface clean. Upon returning to the weightlessness of lunar orbit, Conrad and Bean were immersed in a dense cloud of floating dust that had accumulated in the Lunar Module's (LM) cabin, threatening not only instruments and filters, but the crew's concentration as well. After the LM had docked with the Command Module, Dick Gordon famously kept the hatch closed until Conrad and Bean tidied up. However, dust still floated into the command module's cabin.

The magnitude of Apollo 12's challenges led to the creation of procedures for coping with dust on later missions. Based particularly on the recommendation of Alan Bean, a plan for dust mitigation was devised that included the "dust brush," a special brush designed to remove dust from extra vehicular activity (EVA) suits and other surfaces. Astronauts on later missions stored the bottom section of their EVA suits in closable bags while inside the

"THE DUST ISSUE IS ONE THAT JUST HAS TO BE ADDRESSED. IT'S GOING TO BE THE MAJOR ENVIRONMENTAL ISSUE FOR FUTURE MISSIONS ON BOTH THE MOON AND MARS . . . IT'S GOING TO REQUIRE CAREFUL THOUGHT TO DESIGN SUITS THAT CAN HANDLE 100 OR 200 OR 300 EVAS COMPARED WITH THE THREE THAT WE DID."
HARRISON SCHMITT, APOLLO 17

This photo of Apollo 17's lunar rover replacement fender, crafted on-site after the original was broken, also shows the traverse gravimeter (blue box, top left) with adhered dust after miles of driving.
Credit: NASA

lunar module, helping to protect the cabin and instruments from dust. However, dust continued to be an issue, with Apollo 15, 16, and 17 spending hours of precious EVA time on housekeeping tasks such as cleaning and removing dust from the ALSEP lunar surface experiments, film cameras, the lunar rover's TV camera, and other sensitive equipment. Before the conclusion of an EVA, upwards of half an hour was spent brushing dust off the suits, followed by two to three hours of cleaning inside the LM.

Despite the lengthy dusting, the dust particles were simply too small and sticky to remove entirely. The filters and valves of the Lunar Module's life support system were regularly clogged. Seals on the EVA suits were becoming damaged by the dust, especially the wrist seals. Ken Mattingly noted that soon after rendezvous and docking, the previously clean Command Module already had a thin layer of dust from the Lunar Module coating its panels. Gene Cernan returned home with dust embedded in the pink of his fingernails. These examples

The legs of Harrison Schmitt's EVA suit, coated in dust, blend in with the lunar surface at Camelot Crater during Apollo 17. Credit: NASA

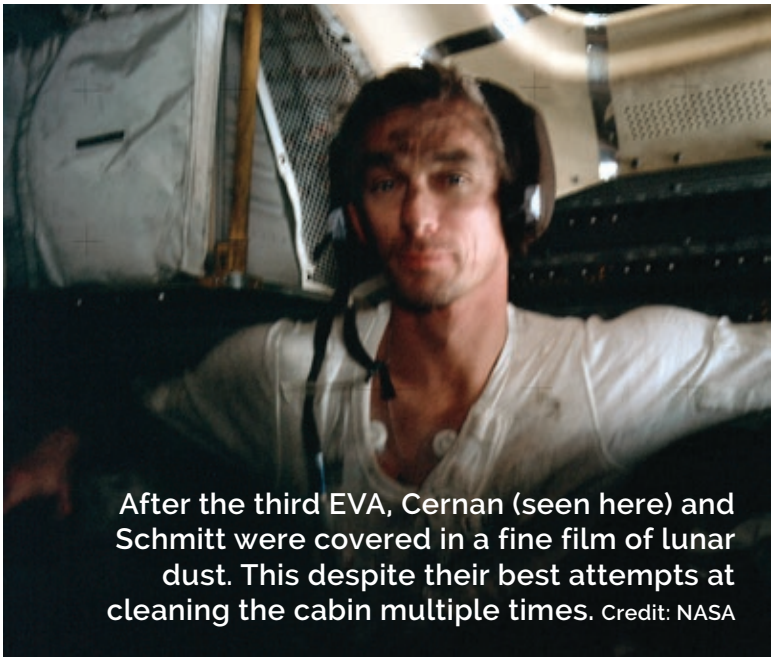
Gene Cernan's moonsuit was a pristine white at the beginning of the Apollo 17 misson, but by the end of the last EVA was filthy. Credit: NASA

are noteworthy for a mere three-day visit to the Moon's surface, and coping with lunar dust during longer stays will be far more challenging.

Returning to the Moon will require the development of an ECLSS design that can operate by removing the dust, or that can continue to operate despite it. Top engineers in the field such as Paragon Space Development Systems' Grant Anderson have noted that testing these systems must be done on-site, and suggest that temporary structures could evaluate environmental control on the Moon before the construction of a long-term base. John Cain of the Florida Institute of Technology considered such proposals in a 2010 paper. An experiment underway by NASA researcher Carlos Calle, called the Electrodynamic Dust Shield, is designed to remove dust using an electromagnetic field by taking advantage of its electrostatic charge. This technique is being tested in space aboard the International Space Station.

Medical researchers are assessing Moon dust's danger to human health using terrestrial simulants. Numerous studies have concluded that prolonged exposure to lunar dust, 90 days or more, can cause permanent damage to the lungs' macrophages, immune cells that filter foreign substances, causing inflammation, pulmonary fibrosis, and other ailments. Topically, it is a skin and eye irritant, and also contains known carcinogens. Despite strong consensus on the effectiveness of lunar simulants for research, each study reinforces that lunar dust's effects on the body are still largely uncharacterized. Actual lunar dust has properties that the simulants do not, such as exposure to radiation, micrometeorites, and solar wind. Lunar dust is also more reactive, exuding a gunpowder-like smell when first exposed to oxygen, and experiments have shown that in low-gravity environments, the dust particles are more easily inhaled in greater amounts.

The dust problem does not end on the Moon, as Mars dust will pose similar challenges. In certain locations, Martian dust is believed to be smaller in size—comparable to smoke—and more toxic than lunar dust. Mars also has dust storms than can last for weeks at a time. The Moon-to-Mars approach will help test dust mitigation technologies, but learning to manage lunar dust alone remains a significant obstacle in the immediate future of space exploration.



After the third EVA, Cernan (seen here) and Schmitt were covered in a fine film of lunar dust. This despite their best attempts at cleaning the cabin multiple times. Credit: NASA

Remembering Apollo

WITH NSS CHAPTERS

Claire Stephens McMurray

The year 2019 saw the 50th anniversaries of three lunar missions (Apollo 10, Apollo 11, and Apollo 12), so the NSS asked its chapters to celebrate these landmark events. In addition to various individual chapter commemorations of Apollo 11, **Joseph Bland** (Chapters Assembly Chair) and the **Sacramento L5** chapter **(SAC5)** hosted web-based events for all three missions in cooperation with the **Chapters Assembly**. Participants shared their memories and the impact that Apollo had on their lives.

APOLLO 10–DRESS REHEARSAL FOR LUNAR LANDING: MAY 18–26, 1969

Apollo 10 mission patch. Credit: NASA

Apollo 10 was the first flight of a complete, crewed Apollo spacecraft to operate in lunar orbit. To test NASA's plans for a lunar landing, Tom Stafford and Gene Cernan entered the Lunar Module (LM) and undocked from the Command Module. They flew a brief station-keeping orbit and simulated a lunar landing by firing the LM's descent engine, staging, then firing the ascent engine and docking with the Command Module. In between, the astronauts raised and lowered the LM's orbit, tested the landing radar, and flew over Landing Site Two in the Sea of Tranquility. When they jettisoned the descent stage, an incorrect switch setting (later attributed to an error in a flight-plan checklist) resulted in uncontrollable gyrations of the ascent stage, but the two corrected the spin quickly and headed back to orbit. Apollo 10 was on the back side of the Moon when John Young restarted the Command Module's engine for the trans-Earth injection, and flight controllers nearly turned blue while waiting to hear that the maneuver was successful. Days later, the capsule splashed down in the Pacific Ocean within visual range of its primary recovery ship, the *U.S.S. Princeton*.

For this first Apollo anniversary virtual event, the Chapters Assembly team started small. Several chapter members and friends gathered at Bland's home to meet with others who contributed their thoughts and memories virtually. This was not a moderated webinar with designated speakers, but more of a multi-location party.

APOLLO MISSION 11–FIRST HUMAN LUNAR LANDING: JULY 16–24, 1969

The Apollo 11 landing was watched worldwide in 1969, and remembered in 2019 by participants from Africa, Asia, Europe, India, and Central and North America. Hosted by Bland and **Avinash Shirode** (**Nashik** chapter president), the Chapters Assembly's first moderated webinar took place on Saturday, July 21st. Apollo 11's Lunar Module *Eagle* landed on the Moon on July 20th, 1969, but Neil Armstrong and Buzz Aldrin were told to rest and dine before exiting the LM. So the morning (for U.S. chapters) celebration on the 21st was designated *Breakfast on the Moon*. In Nashik, India, where this was 7:30 PM on July 22nd, hundreds of students attended the webinar session organized by Shirode.

The Chapters Assembly webinar screen during the Apollo 11 celebration. Credit: NSS Chapters Assembly

Presenters included NSS Chapters Vice President **Larry Ahearn** (who discussed the role of NSS chapters), California Congressman **Ami Bera**, and **Ron Jones** of the NSS Board. **Stevan Akerley**, the NSS Space Ambassadors Program Director, talked about the outreach program, and **Peter Kokh** explained how the Apollo program inspired his 30 years of editing the Moon Miners Manifesto newsletter as well as his new book, *Living on the Moon*. **Dr. Bettye Walker**, President and CEO of the A-MAN STEM International Science Center, discussed how they are working with the **Cape Town Space Society** chapter. **Professor Hildreth (Hal) Walker, Jr.** (co-founder of the Cape Town chapter), spoke about conducting NASA's Apollo 11 Laser Ranging Experiment, which refined the Moon's changing

distance from Earth. Finally, Shirode called up secondary school students who had questions for various presenters.

The **St. Louis Space Frontier Society**, **Sacramento L5 Society**, and **Genesis** chapters each organized group sessions to share three of the limited interactive slots. Individual attendees included Michael Stennecken (**German Space Society**), Elena Veli (**Greek Newspace Society**), Doug Jones (in Central America), Phyllis Redhair (**Phoenix**), Brian Dolezal (**Cuyahoga Valley**), Jack Kennedy (Appalachian Colony), Bill Kranz (**St. Louis**), Kris Cerone and Seth Potter (**Oasis**), Randy Gigante (**DC-L5**), Ed Kulis (**Sacramento L5**), Nathan Price (**North Houston**), Claire McMurray (**Oklahoma Space Alliance**), Perri Doutre (an NSS Space Ambassador), and Fred Becker (*Downlink* editor and District Organizer).

APOLLO MISSION 12–FIRST SUCCESSFUL LUNAR PRECISION LANDING: NOVEMBER 12–24, 1969

The crew of Apollo 12 from left to right: Pete Conrad, Dick Gordon, and Al Bean.
Credit: NASA

Although much of the world watched Apollo 11 land on the Moon, interest diminished after the crew returned safely to Earth. Television networks carried fewer crew broadcasts from space until Apollo 13 got into trouble, so it's no surprise the Apollo 12 webinar was on the shorter side. When the webinar started, Bland spoke about the mission and then began calling on scheduled speakers.

Clifford R, McMurray, space historian, writer, and former NSS Board member, briefly described the Apollo 12 mission and crew. He presented two exciting moments which came close to ending the mission before it had even begun—a lightning strike on the spacecraft just 36 seconds after launch which caused all telemetry to drop out, and another at 52 seconds which took the inertial guidance platform offline. One of the key objectives of the mission was a precision landing on the Moon within sight of the Surveyor 3 spacecraft and retrieval of the probe's TV camera for examination. Back on Earth that examination initially suggested that germs had survived on Surveyor, but years later NASA decided the clean room had been incompletely sanitized. Brilliant cooperation between Mission Control and the crew led to success on the Moon and a safe return to Earth for astronauts Pete Conrad, Al Bean, and Dick Gordon.

Other notable contributors to the Apollo 12 webinar included:

Gerald Blackburn, an aerospace engineer with 40 years of experience working on Apollo and other NASA programs, who started the Aerospace Legacy Foundation after retiring in 2003. Through the foundation, he led the effort to establish the Columbia Memorial Space Center on the site of the old North American Rockwell plant. Blackburn focuses his public lectures on the history of what was accomplished by the former aerospace giant.

Dr. Anthony Paustian, the ISDC Chair for 2020 and award-winning author who has written for *Ad Astra* about the Apollo missions. A former Air Force pilot, he is presently a college provost in Iowa working to inspire young people towards STEM careers. He knew Al Bean personally and is especially interested in Bean's paintings, which provided the only subjective views of the Moon from an astronaut's perspective. Paustian said, among other things, that Bean considered himself an artist first and an astronaut second.

Dr. Lawrence Kuznetz is a 40-year veteran of the space program with advanced degrees from Columbia University and the University of California, Berkeley. He was a flight controller during the Apollo program, helped build the space shuttles, and was the Life Science Experiment Manager for the International Space Station. He spoke frequently throughout the webinar, offering interesting anecdotes about both his career and Apollo 12.

The program lasted for about two hours with 61 people in attendance. Although this webinar had slots for numerous attendees, only 40 slots allowed those logged in to speak. After the invited speakers presented, there were comments and questions from other attendees. **German Space Society** president Michael Stennecken noted that their "touring Apollo exhibition is now in Europe's former largest mining town of Bergkamen, and that their second stationary exhibition in the Münster Natural History Museum was on the anniversary [Saturday] visited by about 800 people."

Those who missed the webinar can watch it later on the NSS YouTube channel, where the previous Apollo 11 program has already been made available.

MORE ON ISDC 2019

IT'S NOT (JUST) ROCKET SCIENCE

Clifford R. McMurray

Stop a random passerby on the street and ask them what people talk about at the International Space Development Conference, and you'll probably get an answer like, "Rockets and spaceships, I suppose." The respondent would probably never guess that attendees at the National Space Society's annual conference talk about making movies, attracting venture capital, private property rights and real estate development, traffic control, 3D printing of buildings with cement, and agriculture. Of course, they also talk about rockets and spaceships. But they talk about them as a means to the end of expanding human civilization across the solar system, and more than just its means of transportation. With four full days of programming, dozens of speakers, and two special policy forums the day before the official start of the conference, there was plenty to talk about in 2019.

The 38th annual gathering of the space community was held in Arlington, Virginia. It was an appropriate forum to discuss politics and legislative policy for a conference whose theme was "Back to the Moon to Stay." NASA Administrator Jim Bridenstine addressed the conference about NASA's plans to put "the first American woman and the next American man" on the south polar region of the Moon by 2024. "We don't need to retire the technical risk, we need to retire the political risk" of going back to the Moon, he said. "We do that by going faster." The new timeline is accelerated from 2028 at the direction of the Trump administration; the program is now called Artemis. The contract for the first element of the architecture, the Power and Propulsion Element of the Lunar Gateway, has already been awarded to Maxar, and may launch in 2022. "We aren't going back to the Moon, we're going forward to the Moon," Bridenstine declared. "This is the Artemis generation."

Artemis will not be business as usual for NASA. Instead of developing all the hardware in house, NASA's deputy associate administrator for exploration in its Science Mission Directorate says they will be paying for some of the transportation on commercial carriers, such as the winners of the first contracts from the Commercial Lunar Payload Services program of unscrewed precursor missions. The first NASA instruments to the lunar surface in half a century may touch down in 2021, riding landers from Astrobotic and Intuitive Machines.

How much returning to the Moon will cost, and whether Congress will go along with the administration's plans, are questions of intense discussion in the space community. Scott Pace, executive secretary of the National Space Council, told his ISDC audience that "within a relatively flat [budget] in constant dollar terms, I think we can have a sustainable program to the Moon. Whether it expands beyond that . . . into resource extraction or other things like that—that needs to be on a business case. It's not going to be because government drops a lot of money on it." But what NASA can do, Pace said, is survey the available lunar resources such as ice at the poles, and conduct the first in-situ resource utilization experiments.

Pace admitted to having "a low L5 membership number," which is to say he was an early member of the L5 Society, the activist group that eventually became the National Space Society. He praised the NSS for its ongoing role in stimulating the space movement. "I think the value of this organization is that it leads to new ideas," he said. "Every innovative policy idea, whether starting with suborbital tourism, commercial space launch, private space facilities, property rights—all of these things have come out of the grassroots community."

Another long-term NSS member, astronaut Eileen Collins, urged her audience to "Keep doing what you're doing. It's important." The four-time shuttle astronaut and first woman to command a shuttle mission was on hand to accept an NSS Space Pioneer Award for Historic Space Achievement. This award was also presented to Apollo 15 command module pilot Al Worden and Apollo lead flight director Gerry Griffin. Collins, Worden, and Griffin shared their experiences of these historic flights and took questions from the floor. Collins recalled her first trip to space, when her commander had to tell his dedicated crewmate, "Eileen, stop working so hard. Look out the window. This is your first sunrise in space." When she looked out the window, she was astonished. "Earth is round! Can you believe that?"

Jeffrey Manber, CEO of Nanoracks, was awarded a Space Pioneer Award for Entrepreneurship. Manber started Nanoracks in his garage, with no investors, in 2009. He now has 70 employees, and is proud that the average employee age keeps dropping. Nanoracks has led the way in commercialization of the International Space Station (ISS), sending more than 750 payloads from 34 nations to the ISS, and deploying more than 230 cubesats from that platform. Among the recent commercial experiments flown by Nanoracks was a two year test of new flavors for Scotch whiskey by the whiskey maker Ardbeg. They found that two years on the ISS was equivalent to five years aging on the ground for whiskey terpenes.

NSS governor Janet Ivey presents the Space Pioneer Award to Eileen Collins.
Credit: NSS/Keith Zacharski

Nanoracks wasn't Manber's first foray into commercializing space stations. In the 1990s he headed MirCorp, which tried unsuccessfully to commercialize Russia's Mir space station. Before political pressures forced it to fold, MirCorp had flown the first commercial human

Jeffrey Manber of Nanoracks speaks at ISDC 2019
Credit: NSS/Keith Zacharski

space mission, and signed the first contract for a space tourist flight with Dennis Tito. Nanoracks has had a long struggle to liberalize NASA's rules for commercial activity on its part of the ISS. He said that with the most recent NASA rules, "we're getting close to what we did with MirCorp."

The Wernher von Braun Award, the National Space Society's highest award, recognizes excellence in management and leadership of a significant space-related project. This year the award was presented to Salvatore "Tory" Bruno, visionary CEO of United Launch Alliance. Bruno's acceptance speech was as stirring as any words ever spoken at an ISDC. "Today our children and our grandchildren look into a future of ever-diminishing resources, hoping only to liver smaller lives of more modest footprints. And yet in our own neighborhood we have this tremendous wealth just waiting for us to reach out and grasp it. And when we do that, it's going to change everything . . . Our children, our grandchildren will inherit a post-scarcity future that will fundamentally change what it means to be human. You will see it. It will come to pass in your lifetime. You will help to make it happen."

The tremendous wealth of which he spoke is the ice and minerals on the Moon and near Earth asteroids. The key to those resources begins with the 20 billion metric tons of water ice in the permanently shadowed craters of the Moon's poles. Scott Pace may not be sure of the business case for harvesting that ice and turning it into hydrogen and rocket fuel, but Bruno is planning to run a ULA rocket on it, and has even named the price at which they are willing to buy it—3,000 dollars per kilogram delivered to low Earth orbit. Bruno said he doesn't expect ULA to be the company mining lunar and asteroid ice; he wants to be a customer for the fuel as "the trucking company of cislunar space." He believes the competition he's getting from newer companies is healthy, noting that it spurred ULA to cut the cost of its Atlas V launcher by one-third. The new Vulcan launch vehicle ULA is developing is approaching the reusability problem differently than SpaceX and Blue Origin have. Instead of recovering the whole first stage, the Vulcan will detach just the high-value engine package and recover it with a hypersonic inflatable heat shield and paraglider. This should enable the Vulcan to recover its cost in just two or three flights, versus ten flights for a Falcon booster, "and then the market will tell us what the right answer is."

Once people start living on the Moon, someone is going to need to build houses for them. Since a single brick hauled up from Earth would currently cost between 50,000 and 200,000 dollars, they'll need to do it with lunar materials. Dr. Behrokh Khoshnevis, the CEO of Contour Crafting, is a pioneer in using 3D printing to create buildings on Earth, with more than 100 patents to his credit. With seed money from NASA's Innovative Advanced Concepts program, he examined what's necessary to translate that technology to lunar applications, created a lunar concrete with melted sulphur mixed with lunar regolith, and extruded it into building forms with a 3D printer. In addition to demonstrating construction of various buildings and spacecraft hangars, he developed a technique he calls "selective separation sintering" to make landing pads or roads by using microwaves to fuse the lunar regolith into solid tiles.

"Space has always been in my heart and mind, although I didn't have much of a background working in it," said Khoshnevis. "I really believe that the future of humanity is in space. This one planet is too fragile and too little for such an amazing species as us." With luck, he'll have the chance to use his technologies to help bring that future into existence.

One potential obstacle to a bright future in space is the growing amount of debris in Earth orbit and the hazard it poses to space traffic. Dr. Nodir Adilov, a professor of economics at Purdue University, used the zombie analogy: "If you're hit by debris, you become debris." With companies like SpaceX's Starlink, OneWeb, and Amazon proposing to launch new constellations of thousands of satellites, the number of active satellites in orbit may increase tenfold within the next decade. All those satellites will have very little maneuverability, so the odds of getting hit and creating more debris will go up exponentially unless something is done to prevent collisions. There are already more than 100 million pieces of debris in orbit; many are as small as one millimeter diameter, but some are as large as buses. Dr. Marshall Kaplan of Launchspace Technologies Corporation noted that we can detect only about 25,000 of those objects—the ones above 10 centimeters in diameter—but at collision speeds up to 32,850 miles per hour (14.6 kilometers per second), even the small pieces can be lethal. He calculates that about 140 inert upper rocket stages, the largest of the debris, pass through the orbital altitude of the ISS every five hours. Launchspace is looking for commercial contracts to clean up the debris.

Jerome Pearson is best known as a co-inventor of the space elevator concept, but his presentation focused on a space debris solution. His company, Star Technology and Research, has developed a satellite called EDDE (Electrodynamic Debris Eliminator). EDDE weighs only 52 pounds (24 kilograms), but a dozen could clean up all the debris bigger than about 2.2 pounds (1 kg), or about the size of a softball, in about seven years, at a cost of 350 dollars per kilogram—cheaper than any other solution proposed. EDDE would deploy a long tether and charge it with electricity from its solar panels; the charged tether would push against the Earth's magnetic field to move EDDE to any desired orbit, snag the debris with a net, and tow it to an orbit low enough to reenter the atmosphere and burn up. Since it uses no fuel to maneuver, its mission is limited only by the number of nets it can carry. Pearson hopes to have an EDDE demonstration in orbit within two years.

Space elevators were featured in their own track. The consensus of the speakers was that elevators to orbit can be a reality "sooner than you think," perhaps in just 15 years and at a cost of 10 to 15 billion dollars. "I've been involved in the startup of three huge major programs," said Michael Fitzgerald of Galactic Harbor Associates. "The space elevator is more ready than all three of those, and all three of those [were successful]." A space elevator would be a tremendous breakthrough in space transportation, at just 50 cents per pound electricity cost to raise the elevator and its contents to orbit.

These are just a handful of the dozens of ideas discussed at last year's ISDC. This year's conference will be held in Frisco, Texas, on May 28 to 31. Make plans to join us to talk about agriculture and law, heavy construction, finance, and, of course, rockets and spacecraft.

Mexican University Students
TAKE ON LUNAR ROBOTICS

Professor Aida Wofford, National Autonomous University of Mexico, Institute of Astronomy • Alfred Anzaldúa, Executive Vice President of the NSS

Al Anzaldua, center, and David Cheuvront worked with more than 100 students, professors and mentors.
Credit: Alfred Anzaldúa

The first Mexican lunar rover competition for undergraduate students, *Hacia una Base Lunar* (Toward a Lunar Base), has been completed. Fifty-six teams registered in the first phase of the competition from 13 Mexican states and 32 institutions. The goal of the competition is to build a rover that can be maneuvered remotely from a control room and travel through a 9,687-square-foot (900-square-meter) simulation of lunar terrain, which includes rocky and sandy areas, a slope, and a crater. The rover must collect, weigh, and carry at least two pounds (just under one kilogram) of rocks, measure and transmit slope inclination and temperature readings, transmit images of nearby terrain, and continuously report its location. Finally, the rover must be able to recover from a 15-second power interruption. Only 15 minutes are allotted to complete the demonstration mission.

The contest originated at the Astronomy Institute of the *Universidad Nacional Autónoma de México* (UNAM), the largest public university in Mexico, and was crafted by enthusiastic scientists and engineers from a number of institutions with input from NSS representatives Alfred Anzaldúa and David Dunlop, and Pacific International Space Center for Exploration Systems (PISCES) representative Rodrigo Romo. The Mexican Space Agency and the Aerospace Cluster of Baja California are also involved as supporters. The terrain for the final stage of the competition is located on the campus of the *Instituto Tecnológico de Ensenada* in Baja California, Mexico. The director and coordinator of the competition is Professor Wofford from the Institute of Astronomy at UNAM.

The first phase of the contest was a design workshop that took place in July, 2019, at the *Universidad Autónoma de Nuevo León* in Monterrey, Mexico. The attendees heard talks from NSS Executive Vice President Alfred Anzaldúa, retired NASA engineer David Cheuvront, and PISCES Program Director Rodrigo Romo. The second phase of the competition took place in October 2019 at the *Universidad Popular Autónoma del Estado de Puebla* and the *Instituto Nacional de Astrofísica, Óptica y Electrónica*, both in Puebla, Mexico. For this part of the competition, students submitted a design document, a project plan, and a video of a functional part of the rover during a 20-minute presentation. Students also attended two talks, one by Dr. María de la Luz Cruz García on the telecommunications system of the Mexican AzTechSat-1, which will be launched from the International Space Station on December 4, 2019, and another entitled *Understanding Lunar Geology to Improve Lunar Base Design* by retired NASA Mission Controller Charles Galindo, Jr.

Nine judges, including the 2018 champion of the FIRST Robotics Competition (Mexican student Xavier Balladarez), selected the best 20 teams to compete in the final competition that will be held next year in Baja California, Mexico. The student winners will attend the International Space Development Conference© in Dallas during June 2020 to exhibit their rovers, show videos, and give a presentation.

The competition is fierce; teams carried out extensive research about lunar surface conditions and carefully planned their strategies to maximize the points they received during the final competition. Professor Wofford has already asked the students to suggest a topic for next year's robotics competition—a popular response has been robotic systems to establish a radio telescope on the far side of the Moon.

TITLE: The High Frontier: An Easier Way

AUTHOR: Tom Marotta and Al Globus **FORMAT:** Paperback, Kindle **PAGES:** 114 **PUBLISHER:** CreateSpace
ISBN-10: 0464706300 **DATE:** July 2018 **RETAIL PRICE:** $22.99/$4.99 **CATEGORY:** Nonfiction

>> Reviewed by David Brandt-Erichsen <<

This book can be considered a worthy update to Gerard K. O'Neill's seminal *The High Frontier* (published in 1977), and authors Tom Marotta and Al Globus should be commended on making a major contribution to the subject. Gerard's widow Tasha O'Neill even gave the authors permission to use the title.

O'Neill envisioned large orbital space settlements, built from non-terrestrial materials, which could eventually be located anywhere in the solar system and built in sufficient numbers that the total land area would greatly exceed the total land area of planetary surfaces, including Earth and Mars. But the problem has always been (and remains)—how do we get from here to there? There is an enormous gap between where we are now and the first orbital space settlements, and even after 40 years there are as yet no concrete plans to actually proceed with building any. This book provides new ideas on a step-by-step approach that can help bridge that gap.

The High Frontier: An Easier Way is written in a lively, highly readable style that is easily accessible to the non-technical reader, yet with sufficient detail to satisfy those who want to know exactly how the authors have reached their conclusions. Author Tom Marotta is an analyst in the Office of Commercial Space Transportation at the Federal Aviation Administration. Al Globus is on the Board of Directors of the National Space Society, has worked in various capacities at the NASA Ames Research Center, and has conducted the annual NASA Ames Space Settlement Contest for 6th to 12th grade students since 1994.

Besides presenting an excellent overview of the subject, the book offers new ideas from studies for which Globus was the principal author. The original studies in the late 1970s assumed a rate of two rotations per minute for orbital space settlements, a conservative number chosen to prevent motion sickness. Globus' studies of the literature since then concluded that this number was too conservative and that four rotations per minute or even higher could be used. This means that "starter" orbital settlements can be considerably smaller and less expensive than previously thought.

The original studies assumed that over 90 percent of the mass of an orbital space settlement would consist of radiation shielding. Globus' studies of radiation data from the International Space Station and a NASA radiation calculation tool (called OLTARIS), however, revealed a location where radiation is low enough that no radiation shielding would be required: equatorial low Earth orbit, located about 500 miles up. Radiation shielding here is provided courtesy of Earth's magnetic field.

The combination of these two factors means that a "starter" orbital settlement in equatorial low Earth orbit could be built with a feasible number of launches of SpaceX's upcoming Starship, and along an evolutionary path leading from space tourism to small space hotels and settlements—a step-by-step approach where each step, with a little luck, could be economically viable.

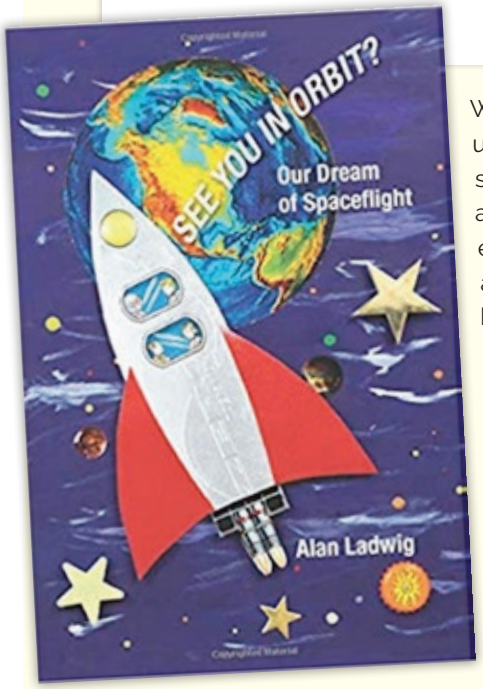
Note that such settlements differ from O'Neill's original concept in two significant ways: they do not require non-terrestrial materials (hence, although cheaper, they don't open up the resources of the solar system), and they cannot be moved outside of Earth's magnetic field (so they don't truly "escape the bonds of Earth"). But they are a step along the right path, allowing their creators to gain experience, develop a space economy, and make subsequent steps easier to accomplish.

I highly recommend this book, not only for its new information but its engaging style, which includes human-interest profiles of some of the people who are making this happen, from Soviet rocket scientist Konstantin Tsiolkovsky to National Space Society Secretary Anita Gale.

TITLE: See You in Orbit: Our Dream of Spaceflight

AUTHOR: Alan Ladwig **FORMAT:** Paperback, Kindle **PAGES:** 500 **PUBLISHER:** To Orbit Productions
ISBN-10: 1733265708 **DATE:** October 9, 2019 **RETAIL PRICE:** Paperback, $18; E-book $12 (Kindle) **CATEGORY:** Nonfiction

>> Reviewed by Rod Pyle <<



When you're looking to understand our future in space it's a good idea to ask someone with vast experience in the field, and author Alan Ladwig has spent more than three decades with NASA and the private sector. Through his new book *See You in Orbit: Our Dream of Spaceflight*, he has provided a deep dive into where we've been and where we're going, along with a rare look at the history of NewSpace efforts. The book's overarching message is how we will get ordinary people—not just astronauts—into space, a subject near and dear to many of us.

This is an insider's perspective derived from direct experience in many of the stories he chronicles with insight and wit. A question the book addresses is how we've been promised a bright and vibrant future in space since the end of the Space Race. This future was to include opportunities for regular people to journey into the final frontier. This goal, however, is a bit like the long-awaited human missions to Mars: always said to be in the near future, but it is a future that keeps moving away from us. Today, however, a sea-change is on the horizon, and this time it's real.

The author spends time looking at NASA and its efforts over the years to teach and inspire, as well as help "close the loop" with a more robust—and democratic—human presence in space. The funding that underwrites these efforts is under continuing scrutiny by parts of the federal government, and NASA must make its case with each new budget cycle. This is a shameful waste of energy, because the agency's accomplishments have been inspirational to millions around the globe. Ladwig supports this case with skill, and this book should help to keep the dollars flowing to where they belong with regard to NASA's outreach and education programs.

There is also another theme at work here: the justification for human spaceflight. It is all too tempting for congressional budget cutters to suggest that robots can continue our quest into space less expensively and more safely. While we mourn the loss of a robot on its way to Mars, such a loss does not cripple the soul (or NASA's next mission) in the same way that a loss of human life does. But spaceflight is not easily quantifiable in these terms, and there is very real value to having people in space; one that any member of the NSS understands instinctively. Some of the reasons for this are technical: humans can accomplish more, with greater flexibility and intuition, than any machine in most destinations off-Earth. But beyond this, there is value to the more subjective part of the human experience in space—it inspires us when brave men and woman travel to distant shores in orbit and beyond, and transforms those who have gone.

Some of the more poetic souls who have experienced spaceflight return to Earth to further this inspiration—think of the books by Apollo 11 astronaut Michael Collins and the exploits of ISS astronaut Chris Hadfield. These efforts have a profound effect on society, especially young people who are seeking to define a career path in technical and scientific fields. Toward such ends, when Ludwig was with NASA he managed the Participant in Space program, and through that the Teacher in Space program, which sought to transport teachers, journalists, and other influential people into space and bring their experiences home to the millions of us who wait in wonder. This is a perspective earned by very few, and Ladwig's management of the program (and expression of its value within the book) makes a clear case for the value of such efforts, whether by NASA or the NewSpace companies preparing to carry citizen-astronauts into space.

The book concludes with a look at what the near future might hold for citizen spaceflight, and how those who aren't millionaires might be able to grab a piece of the black skies beyond. As it turns out, there are many ways to do this, ranging from astronaut experiences—at least one of which Ladwig is currently working to prepare—as well as more abstract notions such as sending your DNA into space. Of course, there are dangers involved with spaceflight as well, and risk is a topic that will need to be addressed as regular citizens head into space. As the author puts it, "Failure is not an option, but there is no denying it's an inherent possibility."

While most of us may have to think twice about spending the estimated 250,000 dollars that the early tourist flights are likely to cost, there are other experiences that are affordable to the average person—and will bring us a big step closer to giving many that spaceflight adventure they crave. *See You in Orbit: Our Dream of Spaceflight* will entertain, inform, and inspire any reader who picks up this highly recommended book.

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
202-424-2899

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, Apt 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: Greg Hart
louisvillespace@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_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: Aylyffe Martin
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.edu
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

LOCAL AND SPECIAL INTEREST CHAPTERS [CONT]

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
2359 East Crestmont Lane
Highlands Ranch, CO 80126
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 Nagar 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) - Mumbai
502/5 Aakashganga complex
Vijay Garden, Ghodbunder road
Thane, Maharashtra, 400 607
Contact: Akshat Mohite
akshatmoh@gmail.com
91-869-200-6741

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
Montague 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

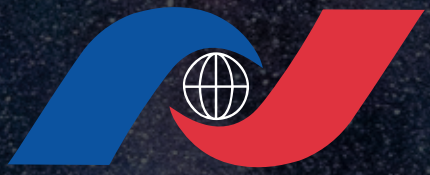
If you support the exploration and development of space and the creation of a spacefaring civilization, joining the National Space Society (NSS) is a good first step. But what if you want to do more?

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 **space.nss.org/nss-chapters-directory**. 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: **space.nss.org/community-chapters**. 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 **space.nss.org/resources-for-chapters** for more details.



National Space Society

NSS BOARD OF DIRECTORS

At-Large Directors
Laurence Ahearn
Dale Amon
Greg Autry
Gary Barnhard
David Brandt-Erichsen
John Charles
Hoyt Davidson
Anita Gale
Al Globus
Buckner Hightower
Alice M. Hoffman
Mark Hopkins
Kirby Ikin
Rob Kelso
K. Dean Larson
Jeffrey Liss
John Mankins
Karen Mermel
Bruce Pittman
Joe Redfield
Dale Skran
Michael Snyder
John K. Strickland, Jr.
Lynne Zielinski

Regional Directors
Region 1:
Madhu Thangavelu
Region 2: Max Fagin
Region 3: Feng Hsu
Region 4: Ron Jones
Region 5: Mike Ryan
Region 6: Todd Kapp
Region 7: Randy Gigante
Region 8: Myrna Coffino

NSS EXECUTIVE COMMITTEE

Chairman, Board of Governors
Karlton Johnson

President
Geoffrey Notkin

Chairman, Board of Directors
Kirby Ikin

Chair of the Executive Committee
Dale Skran

Executive Vice President
Alfred Anzaldua

Senior Vice President & Senior Operating Officer
Bruce Pittman

Vice President, Chapters
Larry Ahearn

Vice President, Development
Hoyt Davidson

Vice President, Membership
Burt Dicht

Vice President, Public Affairs
Lynne Zielinski

Secretary
Anita Gale

Treasurer
Joe Redfield

Assistant Secretary
Michael Snyder

Assistant Treasurer
John K. Strickland, Jr.

NSS BOARD OF GOVERNORS

Karlton Johnson, Chairman
Hugh Downs, Chair Emeritus
Mark Albrecht
Buzz Aldrin
Eric Anderson
Norman R. Augustine
Lance Bass
Howard Bloom
Ben Bova
Bruce Boxleitner
Dan Brandenstein
Tom Cruise
George Dietrich
K. Eric Drexler
Arthur M. Dula
Freeman Dyson
Don Fuqua
Newt Gingrich
Jeff Greason
Harry Hamlin
Tom Hanks
Tanya Harrison
Janet Ivey
Mark Jannot
Edwin Jones
Lon Levin
John S. Lewis
James Lovell
Kenneth Money
Nichelle Nichols
Geoffrey Notkin
Glenn Reynolds
Henk Rogers
Martine Rothblatt
Harrison Schmitt
Michael Simpson
Anthony Tether
Maria von Braun
Gordon Woodcock
Simon "Pete" Worden

NSS ADVISORS

Stephanie Bednarek
David R. Criswell
Marianne Dyson
Daniel Faber
Don M. Flournoy
Graham Gibbs
Jerry Grey
Peter Kokh
Alan Ladwig
Florence Nelson
Ian O'Neill
Chris Peterson
Seth Potter
Stan Rosen
Ken Ruffin
Stanley Schmidt
Rick Tumlinson
Lee Valentine
James Van Laak
Paul Werbos

ADDITIONAL NSS LEADERS

Vice President for Space Development
Greg Autry

Director of Creative Arts
Chantelle Baier

Director of Education
Lynne Zielinski

Director of Information Systems
Jim Plaxco

Director of Strategic Relationships
Gary Barnhard

BUZZ ALDRIN COUNCIL [LIFETIME OF $5000+]

Steve Adamczyk
John Adams
Robert Adolfsen
P. Alpaugh
Edward Apke
Janet Asimov
Daniel Babcock
Jack Bader
Kevin Baines
Roger Bara
Christine Becker
David Blanchard
Blandy Boocock
Susan Bottom
Amy Bouska
Philip Bowman
Christopher Bradley
Greg Brand
Greg Brandt
Bruce Bury
Randall Buss
Christopher Butcher
Reb Butler
Brian Campbell
Paul Canolesio
Louis Clairmont
John Clancy
Bruce Clark
Don A. Coleman
Michael Cronin
Hoyt Davidson
Robert DeBock
Richard E. Deno
Robert Dettmer
Daniel J. Devescovi
Donald Disraeli
Stephen Donaldson
Richard Dowling
Hugh Downs
Mike Dudley
David Ehrlich
Bob Everett
Alfred Ewell
Steven Fenner
Mark Ferrari
Gregg Foote
Marc Foulkrod
Dick Fredericksen
Richard Garriott
Joseph Gillin
Erland Gjessing
Frederick Graboske
David W. Gray
Vincent Greene
Gregory Gudalefsky
Eric Gunnerson
Jim Haislip Jr.
David Hamlin
James Hammond
David Hampton
Ed Harris
Alfred Henneberger
Mark Herrup
Daryl Hester
William Hettchen
J. Hirche
Mark Hopkins
Hugh Hotson, Jr.
Mijan Huq
Frank Inferrera
John Irwin
Neil H. Jacoby, Jr.
Steve Jaynes
Chris Jensen
Stephen Jensen
Carol Johnson
Paul Johnson
James Jones
Edwin Jones, Ph.D.
Richard Kacik
David & H.B. Kaplan
William Kelley
Dean Kennedy
David Korpi
Ronnie Lajoie
Barry M. Lamont
Tim Lehmann
J. Michael Lekson
Charles Lenzmeier
Fred C. Link
Michael Livanos
Charles Livingston
Thomas M. Lutgens
David Lyon
Douglas C. Mallory
Gordon Mandell
Leonard Mangini
Matthew Marchese
Don Martin
Pat Martin
Karen Mermel
C. Rick Miller
M. Michael Miller
Gene Milstein
Pamela Monroe
M. Pat Montoure
Mary Morss
Mike Neary
Byron Nichols
Candace Pankanin
Jerald V. Parker
Kevin Parker
John Pascoe
Alexander Peters
John Melvin Pinto
Ed Post
Joshua Powers
John Pritchard
Kent Radek
Joe Redfield
Mike Rees
Pete Ricketts
Bill Rintz
Bina Rothblatt
Gabriel Rothblatt
Martine Rothblatt
David Rucker
Greg Rucker
Edwin Sahakian
Peggy L. Schultz
Gary Scotto
Tim Seeley
David Shulan
Frederick V. Simms
Randall Skinner
Dale Skran Jr.
David Smith
Shirley M. Sontheimer
Gregory Stanley
Russell Stowe
Scott Strobel
Ron Suter
John Swanson
David A. Swingle
Steven Tague
Stephen Thompson
Eric Tilenius
Pat Tomasko
Michael Tomkins
Patrick Trani
Donald Twombly
John Vance
Monica Visinsky
Raymond Visneski
Richard Von Glahn
Sigrid von Hurst
Craig E. Ward
Alan Wasser
Richard C. Waters
Barry Watson
Doug West
George Whitesides
Peter Wilhelm
Jay Wittner
Brian Yanagitani
Cynthia Yarborough

MAJOR DONORS [$350+ IN PAST 12 MONTHS]

Robert Adolfsen
P. Alpaugh
Jeff P. Anderson
Kennith Armour
Daniel Babcock
Jack Bader
Lonnie Bailey
Kevin Baines
Gayle Barrow
Christine Becker
Carolyn Beltz
Cory Boyle
Christopher Bradley
Greg Brand
Greg & Dawn Brown
George & Sandy Bush
Randall Buss
Reb Butler
Tom Caldwell
John Campbell
Barbara Counts
Stewart Davey
Frances Dellutri
Robert Dettmer
Geoffrey A. Dorn
Rick Dotterer
Richard Dowling
Lorna Jean Edmonds
Bruce Egloff
David Ehrlich
Bob Everett
Thomas Furlong
Charles Gould
Charles Green
Vincent Greene
David Hamlin
David Hampton
John L. Hank
Eric Hayes
Thomas B. Hayward
Mark Herrup
Claudia Hester
J. Hirche
Thomas E. Holechko
John Hrivnak
Mijan Huq
Neil L. Inglis
Jeffrey A. Jaschinski
Steve Jaynes
Stephen Jensen
Carol Johnson
Edwin Jones, Ph.D.
Richard Kacik
William Kelley
Phillip Kvamme
Ronnie Lajoie
J. Michael Lekson
Charles Lenzmeier
Fred C. Link
Thomas M. Lutgens
David A. Macys
Douglas C. Mallory
Matthew Marchese
Ken Millard
C. Rick Miller
David Miller
M. Michael Miller
Mark Mosch
Ronald Murdock
Geoffrey Notkin
Jason Orr
Jerald V. Parker
Daniel Pederson
Bruce Pittman
Emery Prior, Jr.
John Pritchard
Michael Rosen
Bina Rothblatt
Martine Rothblatt
Kenneth Ruffin
William Rumsey
Peggy L. Schultz
Tim Seeley
Geoffrey Shiflett
Frederick V. Simms
Randall Skinner
George Sowers
Gregory Stanley
William Sticklen
Russell Stowe
Scott Strobel
Paul Swan
Steven Tague
Alethea Taylor
Eric Tilenius
Michael Tomkins
Edward Veal
Ron Vilas
Doug West
Peter Wilhelm
Brian Yanagitani

National Space Society

JOIN THE TEAM FOR SPACE

Get *Ad Astra*, the award winning magazine of the National Space Society.

ENJOY ALL THE **MEMBER BENEFITS**

MONTHLY + ANNUAL PAYMENT OPTIONS AVAILABLE

FOR ALL MEMBER BENEFITS + AD ASTRA

NSS AWARD-WINNING QUARTERLY MAGAZINE

DOWNLINK NEWSLETTER EVERY TWO WEEKS • ACCESS TO LOCAL CHAPTERS

FREE PROMOTIONAL ITEMS • MONTHLY + ANNUAL PAYMENT OPTIONS AVAILABLE

INVITATIONS AND DISCOUNTS TO NSS SPONSORED EVENTS

FROM SPACEX AND BLUE ORIGIN to the International Space Station, from the Moon to Mars and beyond, the NSS is at the forefront of the new space age. New members can join now with monthly or annual payment options and get a one year subscription to *Ad Astra*, the only magazine of its kind!

MEMBERSHIP MAKES A GREAT GIFT! Bring the gift of space to someone new, and give them the special feeling that comes with knowing they are supporting the greatest adventure of our time.

FOR MORE INFO:

space.nss.org | membership@nss.org | 202.424.2899

CONTINUING THE JOURNEY

The Moon, then Mars **ISDC® 2020**

Experience the future of space development, exploration, and settlement through the words of top speakers, researchers, engineers, and thought leaders including:

Dr. Peggy Whitson
Retired NASA Chief Astronaut

Steve Jurvetson
Co-Founder, Future Ventures

Dr. Phil Plait
The Bad Astronomer

Al Worden
Apollo 15 Astronaut

Steve Kwast
Lieutenant General USAF (Retired)

Dr. Story Musgrave
Retired NASA Astronaut and Physician

Dr. David Gallo
Leading Oceanographer and Explorer

Dr. Marc Rayman
Director & Chief Engineer for NASA/JPL's Dawn Mission

Juno Team
NASA's Juno Mission to Jupiter

Greg Russell
17-Time Oscar-Nominated Sound Mixer/Engineer

National Space Society

ISDC2020.nss.org

International Space Development Conference®

Dallas, Texas • May 28-31, 2020

Embassy Suites by Hilton Dallas-Frisco Hotel & Convention Center