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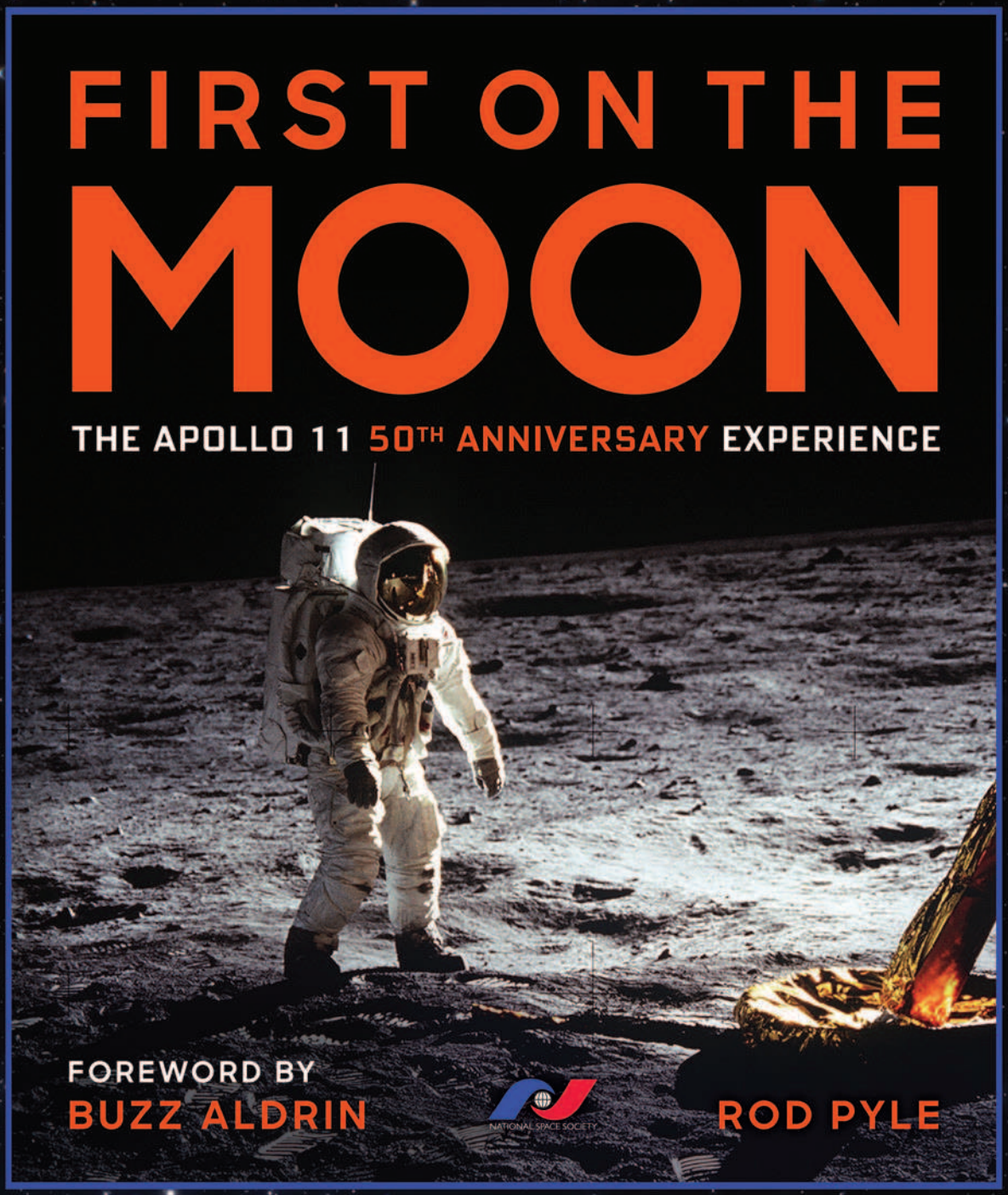

"Packed with archival images and documents, some of them previously unpublished, this book includes a foreword by Buzz Aldrin. It's ... gift-appropriate ... and covers the mission from start to finish. Pyle has written several books on space exploration and is also the author of *The Apollo Missions* (Carlton, Sept.), which annotates first-person accounts from astronauts across the Apollo program."

—*Publishers Weekly*

"Science author Rod Pyle spent years combing NASA archives and private collections for memorabilia from the Apollo 11 mission. First on the Moon: The Apollo 11 50th Anniversary Experience ... brings us rarely seen archival images, as well as photo-compositions previously not available online, here for the first time color corrected and assembled into their originally intended montage format. In addition, the book is foreworded by Buzz Aldrin and includes never-before-published interviews with the children of Aldrin and of Armstrong."

—PopScienceBookClub.com

Published in association with the National Space Society, *First On the Moon: The Apollo 11 50th Anniversary Experience* is available from Barnes & Noble, Amazon and other fine booksellers, now at a reduced price. This prized volume includes rarely-seen images.new photomontages and exclusive interviews with the children of the astronauts. With a foreword by NSS Governor Buzz Aldrin and lavishly presented in hardcover, this is the definitive account of humanity's first steps on another world.

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Credit: James Vaughan

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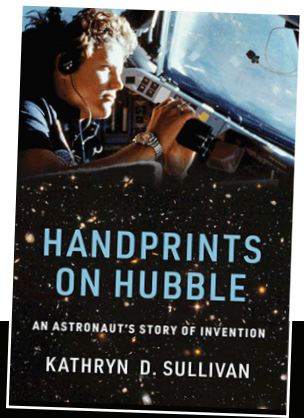


THE NEW SPACE AGE HAS BEGUN

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

What a year of highs and lows 2020 has been. While in the grip of the worst pandemic in a century, we saw the selection of Blue Origin's National Team, Dynetics, and SpaceX to provide commercial transportation services for NASA; the successful launch and return of SpaceX's Demo-2 mission to the ISS; and the selection of Astrobotics to deliver a second robotic payload to the lunar surface in 2023. These are all profound achievements, and once again prove the wisdom of NASA's ongoing efforts to engage private industry in its spaceflight programs.

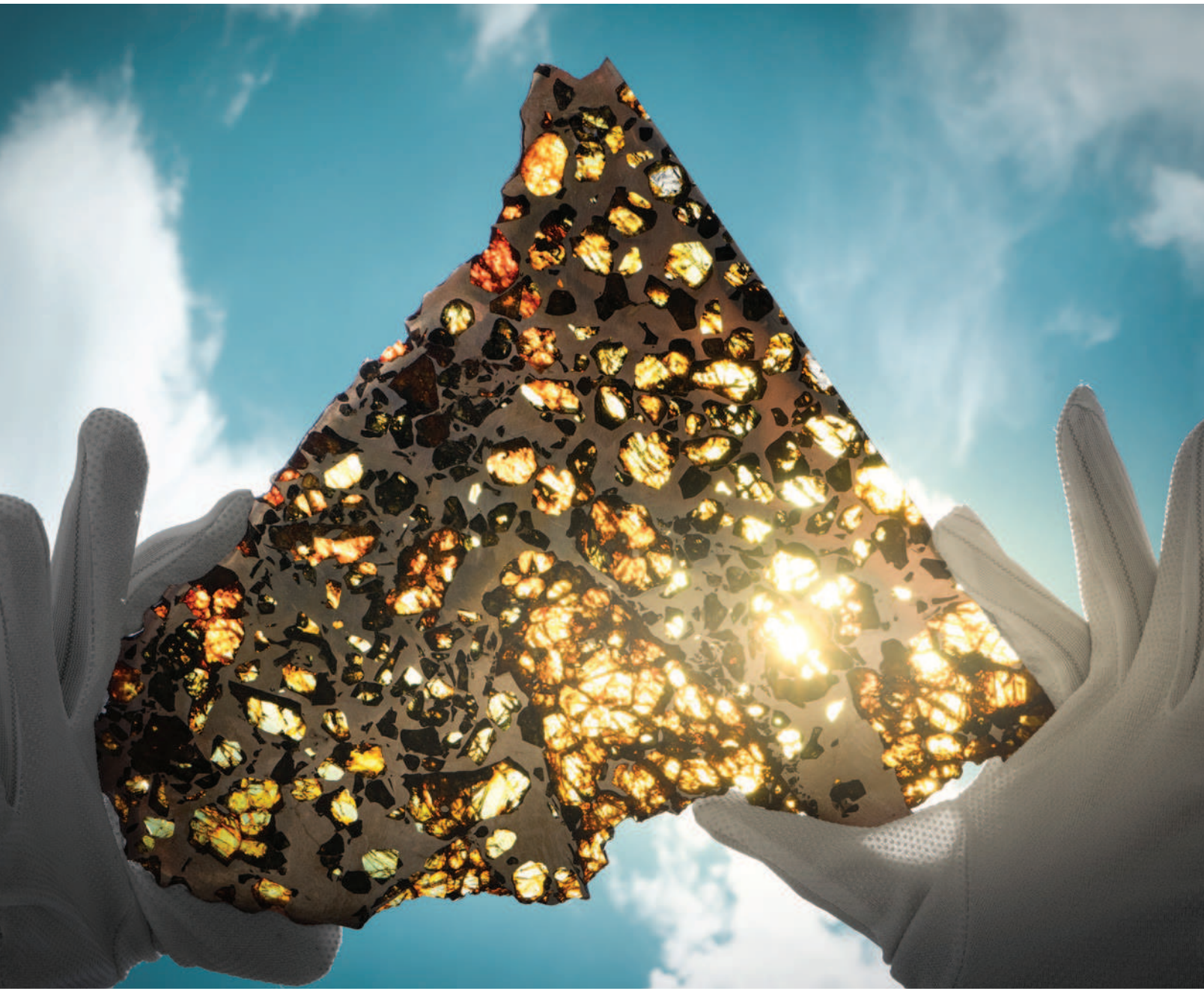
As any regular reader of *Ad Astra* knows, these accomplishments mark a sea change in how spaceflight is accomplished in the U.S. and are due in part to the hard work of citizen groups like the NSS who have tirelessly promoted the Commercial Resupply Services and Commercial Crew programs. These programs have replaced traditional cost-plus contracting between government and industry with fixed-priced agreements. The results have been quite positive, and the savings profound—as NASA describes in a statement, Commercial Crew is "poised to save the agency approximately 20 to 30 billion dollars, and provide two independent crew transportation systems." While we are still awaiting successful tests of Boeing's Starliner crew delivery system, the overall trend is clear: this new arrangement works, and it works well.

However, the savings won't stop there. With delivery of robotic cargo and human crews to the Moon being similarly contracted to private operators, and United Launch Alliance, SpaceX, and others moving aggressively towards providing cislunar transportation on an affordable and regular basis, we appear to be ready to break out of Earth orbit in a major way at last, and are poised to utilize lunar resources to open the solar system to further exploration and settlement. We've waited a long time for this moment, but our efforts appear to be bearing fruit at last.

In this issue of *Ad Astra*, you will find a number of articles addressing these subjects. Michelle Hanlon, Chair of the NSS International Committee and MIT professor, and Alfred Anzaldúa, NSS Executive Vice President and Chair of the Policy Committee, weigh in on the intricacies of space law. John Kross takes a deep dive into the future of the human settlement of cislunar space and the thorny issue of dealing with life-threatening pathogens there. Melissa Silva profiles mover-and-shaker (and NSS governor) Martine Rothblatt and examines the extensive holdings of NSS materials at the New Mexico Museum of Space History. Cliff McMurray looks back at the handling of lunar samples at NASA's Lunar Receiving Laboratory, and Kyla Edison of the Pacific International Space Center for Exploration Systems gives us a view into the astronomical beliefs of the ancient Hawaiians. NSS Vice President of Education and Outreach, Lynne Zielinski, reports on recent developments in the NSS's extensive efforts in youth outreach, and Ben Evans recalls the achievements of the Compton Gamma Ray Observatory, a 37,000-pound (16,783-kilogram) behemoth that gave us our best-ever view of the cosmos at extreme frequencies.

It's a great time in spaceflight history—truly the beginning of a new age of space exploration and development—and the NSS is poised to be a more integral part of this adventure than ever before. But this is also a challenging time for our planet, with the enormous impact of the COVID-19 pandemic affecting us all. Change is in the wind, priorities are understandably shifting, and it will take the efforts of all of us in the NSS to keep the promise of this bright new future in space alive. While we rebuild our lives, our national economies, and our view of the future, we must keep looking upward. *Ad Astra*!

GIVE THE GIFT OF OUTER SPACE ... METEORITES



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THE POWER OF PERSISTENT BOLDNESS

By Alfred B. Anzaldúa, NSS Executive Vice President

A poll released one year ago found that most people in the United States believe that NASA's space program should focus on scientific research, potential asteroid impacts, and robotic space probes instead of sending humans to the Moon or Mars. Considering the NSS's long-term efforts to promote the goal of living and working in space, this result troubled some of my fellow space advocates and caused doubts about our space development strategies and tactics. However, overreacting to common opinion is precisely the wrong lesson to take from this poll.

My traveling and living experiences in and outside of the United States have given me a chance to closely observe people who have managed to bring about great changes through the power of persuasion. I have noticed that "super persuaders" tend to share three basic characteristics:

> They are persistent, play the long game, and do not become discouraged when they fail to achieve their objectives at first or even after repeated attempts.
>
> They build a network of like-minded collaborators or allies by forming amicable and mutually beneficial relationships using personal engagement or their writings.
>
> They do not allow polls or popular opinion to influence their opinions or actions, and they are outliers who promote a singular, bold vision. Instead of staying comfortably within the status quo, they disrupt it.

Examples of famous super persuaders include Martin Luther King Jr., Mahatma Gandhi, Steve Jobs, Elon Musk, Nelson Mandela, and Jeff Bezos. However, embedded in every society are many more that remain largely unnoticed, yet bring about great changes. One such person is W. Edwards Deming, who revolutionized quality industrial management. Even less well known are millions of others spread around the world, trusted experts or trendsetters who can cause sudden changes in social customs or activities. These are the behind-the-scenes people who are sometimes responsible for sudden style changes or who organize "flash" protests.

At some point super influencers, well-known or not, push back against something considered to be common sense. Instead of following the herd, they are guided by an inner vision and, despite failures, persist until they bring about the change they are seeking (which can be positive, negative, or trivial).

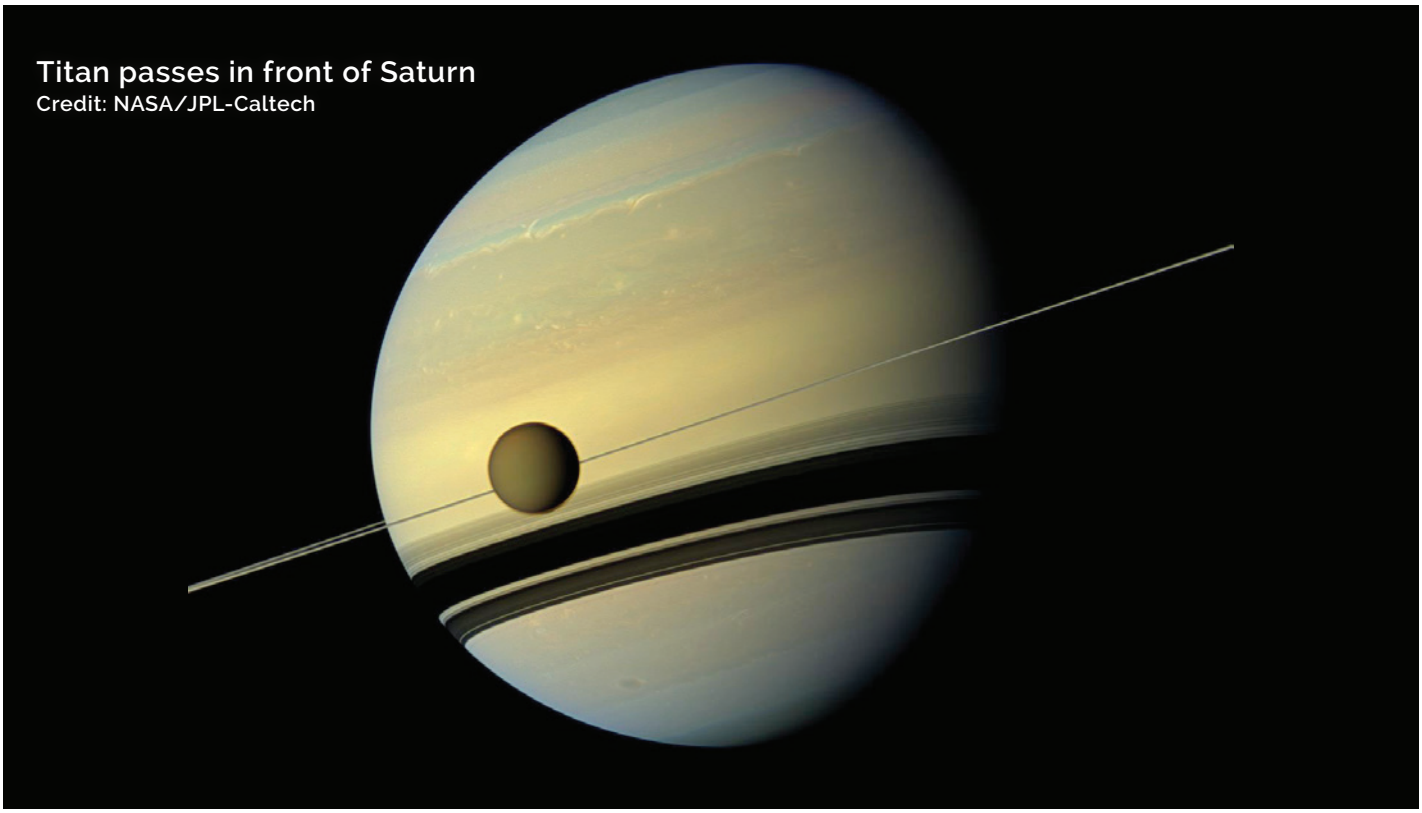
So, what should members of the National Space Society make of last year's space poll? Despite that poll, we see NewSpace companies enthusiastically picking up the mantle of space settlement (some using our settlement terminology). We could congratulate ourselves with the thought that we are winning, and indeed, we are—but just barely. The hard truth is that we have a long way to go before people are living and working in space in thriving communities for the benefit of humans everywhere.

One impediment to realizing our goals is that the NSS generally has not received credit for planting and nurturing the idea of space settlement that some leaders are finally embracing. This lack of recognition hinders our promotional efforts because it means that we must start from scratch to build credibility each time we approach an influencer who has never heard of us. It is hard to say how much further ahead would we be if we were already much more widely known as space development thought leaders.

Luckily, NSS leadership has come to recognize the need to increase awareness of our brand and is taking steps to address this. Nationally, we collaborate with like-minded allies in the Alliance for Space Development to lobby Congress for specific space legislation. We also have begun to use NSS-branded byline articles, press releases, and social media to amplify our space policy recommendations, formerly found only in relatively obscure position papers. Internationally, we have increased our participation in international forums, where we make presentations and distribute papers and articles, as we garner collaborative relationships.

Almost half a century has passed with humans languishing no farther than low Earth orbit, so it is not yet time to celebrate. Instead, let us harness the power of persistent and bold action in collaboration with like-minded allies. Whatever else we do, let us never allow polling or popular opinion to deflect us from our primary mission: to advance humanity to the stars.

COUNTDOWN



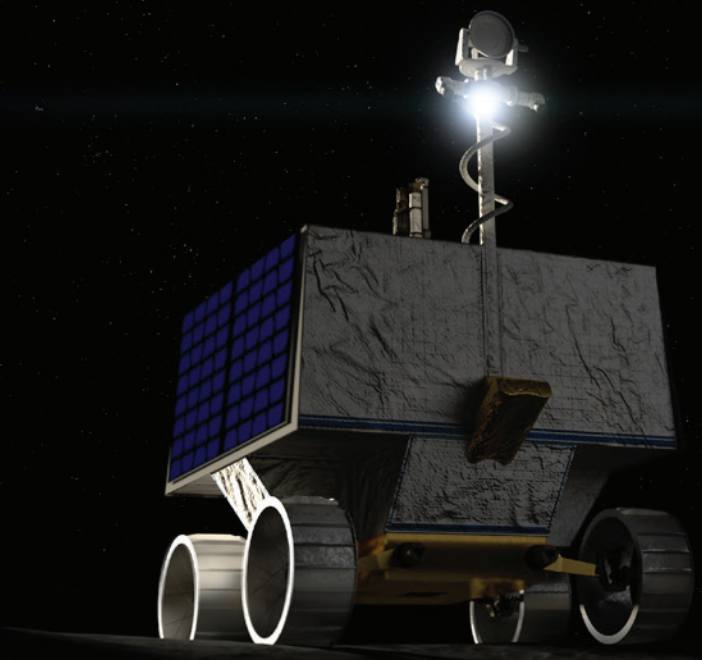
Titan passes in front of Saturn
Credit: NASA/JPL-Caltech

5

SOCIAL DISTANCING FOR TITAN

While people are practicing social distancing, it appears that Saturn's moon Titan has gotten in on the act, moving farther from its parent planet. Though the increased distance is not dramatic, it's occurring about 100 times faster than previously thought. It's taken 4.5 billion years since its formation for Titan to move to its current location of 746,000 miles (1.2 million kilometers) from Saturn, so the rate at which it is now moving was a surprise—over four inches (10.2 centimeters) per year, as opposed to the previously assumed rate of less than one-half inch (1.3 centimeters). This is occurring because moons exert gravitational affects on the planet they orbit, even one as massive as Saturn. This gravitational pull causes heat in the parent planet, and that heat alters the gravitational field of the planet in more profound ways than one might expect. The study looked at 10 years of data using two different techniques, and showed that the complex dance of attraction forces between Titan, Saturn, and the other 50-plus moons of the planet have caused this surprising result. So when people arrive at Titan in perhaps 20 years, we will have an extra seven feet (2.1 meters) to travel to get there. You've been warned.

VIPER FLIES **ASTROBOTIC** 4



The VIPER rover after deployment
Credit: NASA

NASA recently announced that Astrobotic has been granted a second contract to deliver payloads to the lunar surface. The new contract will take the Volatiles Investigating Polar Exploration Rover, or VIPER, to the lunar south pole in late 2023, flying aboard Astrobotic's Griffin lander. NASA's associate administrator for science, Thomas Zurbuchen, said, "The VIPER mission will search for ice and map resources to bring us a significant step closer to NASA's ultimate goal of a sustainable long-term presence on the Moon … This will help make it possible for humans to eventually explore Mars and beyond." The contract is part of NASA's Commercial Lunar Payload Services program, through which the agency contracts commercial companies to fly payloads. The Griffin lander is for larger payloads such as the 1,000-pound (450-kilogram) VIPER; the first Astrobotic lunar contract will be delivered on the smaller Peregrine lander. VIPER will search the south polar region for in-situ resources such as water ice for use in life support and rocket fuel production.

3 | **AN INTERNATIONAL** ARMADA TO MARS

The year 2020 is shaping up to be a big one for Mars. Besides the launch of NASA's Mars 2020 rover Perseverance (the first true astrobiology mission to the Red Planet since the Vikings in the 1970s); the United Arab Emirates (UAE), Japan, and China are headed to Mars. The UAE's Hope mission, called *Al Amal* in Arabic, departed the Tanegashima Space Center in Japan aboard a Japanese H2A rocket in July. The orbiter will study the Martian atmosphere. China's *Tianwen-1* mission is more complex, consisting of an orbiter, a lander, and a rover that will search for biosignatures on the Martian surface. It's going to be a few good years for Mars exploration.

The UAE's Mars orbiter *Al Amal*, also known as Hope
Credit: UAE

Astronauts perform tasks during an early Artemis mission without the added benefit of a rover
Credit: NASA

2 ALAS, NO LUNAR ROVER FOR ARTEMIS

While NASA is aiming for a crewed lunar landing by 2024, the activities that will be undertaken during that first crewed mission, and the attendant equipment needed to accomplish them, are still being developed. One piece of hardware that will apparently not be included is a new lunar rover. While the astronauts are intended to remain on the Moon for over six days, driving to their objectives will not be a part of their activities during the four scheduled Moonwalks, as a new rover is not planned until the second mission at the earliest. Nonetheless, given the quartet of four-hour EVAs, the agency expects the astronauts to cover up to 10 miles (16.1 kilometers) on their own two booted feet. This limit will be dictated by safety concerns over walkback requirements (the distance an astronaut can cover if a suit malfunctions or in case of injury or illness), and the fact that the missions will be focused on the south lunar pole (the Apollo landings were all close to the lunar equator), where the deep cold found there may be a concern.

1 BRAVO, DEMO-2!

On May 30, a SpaceX Crew Dragon was lofted atop a Falcon 9 rocket to rendezvous with the International Space Station as a part of NASA's Commercial Crew program. Astronauts Doug Hurley and Bob Behnken made up the crew and the launch, rendezvous and docking went off without a hitch. This completes the two demonstration flights for SpaceX's part of the program—Boeing still needs to fly another uncrewed test of its Starliner spacecraft—and opens the way for commercial operations to commence on a regular basis, with American spacecraft delivering American astronauts to the station. It was a long haul from the end of the shuttle program in 2011 to the U.S. return to crewed spaceflight, but we're back. Hurley and Behnken returned to Earth on August 2nd. Bravo, SpaceX, for a stellar performance.

Bob Behnken, left, and Doug Hurley in front of the Crew Dragon capsule
Credit: SpaceX

AN APOLLO ASTRONAUT MADE ME DINNER

Why Character is Essential in Leadership

Anthony Paustian, Ph.D.

In March, we lost an Apollo astronaut, a beloved member of the space community, and in my own case, a personal friend—Al Worden, the Command Module Pilot for Apollo 15. To those who knew him, his passing may have come as a bit of a shock, especially in light of his outgoing personality and unlimited energy despite his advanced age.

Al and I became close later in his life. While visiting him last fall at his home in Houston, I assumed we would simply do what we always did; talk space, but also discuss family and politics, while eating out for every meal, as was our routine. This trip was different. While we did dine at restaurants, Al decided he wanted to prepare a dinner at his home. Despite my telling him it wasn't necessary, he was determined, and there was no altering his trajectory once it was set.

While he prepared the lavish spread of steak, potatoes, asparagus, and dessert, I could only watch as he wanted absolutely no help. At that moment, I realized here was one of my personal heroes. Al was a global celebrity, and one of only a handful of people to travel to another heavenly body, making and serving dinner to a common guest. That one simple act completely summed up Al's character. While I've gotten to know many important people and celebrities over the years, I can't see any of them taking the time to make and serve me dinner, let alone treating me as an equal.

Some say a person's true character reveals itself when no one is watching. One's character can inspire or discourage others as well as influence how someone interprets and shapes the world around them. Al Worden inspired many because he genuinely believed in people and was willing to freely help whenever asked, and often even when he wasn't.

However, when observing the behavior of some of today's leaders in both the public and private sectors, it's easy to question whether, as a society, we've lost sight of character. Thousands of books have been written on leadership style, but few have been written on character. This may be because character is difficult to define, is seen as old-fashioned, or because there's no clear consensus on what it is or how to assess it objectively. Words like "authentic" and "transparent" are frequently tossed around as desired leadership qualities, but are they actually qualities, or the result of a leader simply behaving in a manner consistent with their character?

Some have defined character as the sum total of an individual's personality traits and values. However, there are limitless possible personality traits, and values are often based on a personal set of beliefs that can vary widely. Take the concept of quality as an example. Most would agree that good quality is an essential value in the context of producing and purchasing things, yet the degree of quality for anything rests with the perception of the person doing the evaluating. This perception is formed through an assessment of the objective qualities specific to the product in question—the separate elements, features, points of comparison, or components—that help to set it apart.

Al Worden speaking to a group of elementary school children in Iowa
Credit: Anthony Paustian

Worden speaking with Anthony Paustian at ciLive! in 2017
Credit: Jennifer Coleman

On the other hand, the object in question also has subjective qualities—softness, roughness, fit, flavor, and others—that aren't specific to either the object itself or its observer. These qualities come as a result of the interaction between the object, the observer, and the environment surrounding them. The difference between objective and subjective qualities is that the former is based on a sense of measurement while the latter is based on feeling or emotion.

It's this sense of feeling that creates the perception of quality: a sense of attractiveness, excellence, superiority, and worthiness—attributes that are very difficult to observe or quantify, but much easier to have a gut feeling about. Thus, the value of quality is associated with an object insofar as it is perceived to be an instrument for achieving some goal or objective.

People are not objects, but the quality of one's character is often determined in the same manner. Whether through regular observation or a single interaction, people will assess another's character based on their perception of that person's qualities, and that perception is often based on a number of behavioral habits—actions exhibited on a fairly consistent basis. Habitual behavior is developed over time and is therefore a good representation of character.

While the list is long, I believe character is primarily perceived through these five behavioral habits:

Authenticity: authentic leaders are genuine and lead with both their hearts and minds. They walk the talk regardless of the role they're serving and inspire respect through their actions, not just their words. They don't need the spotlight and are happy to cast it onto others. They are open-minded, approachable, and often vulnerable. They are aware of their strengths, limitations, and emotions, don't profess to be something they're not, and unapologetically do what they believe is right.

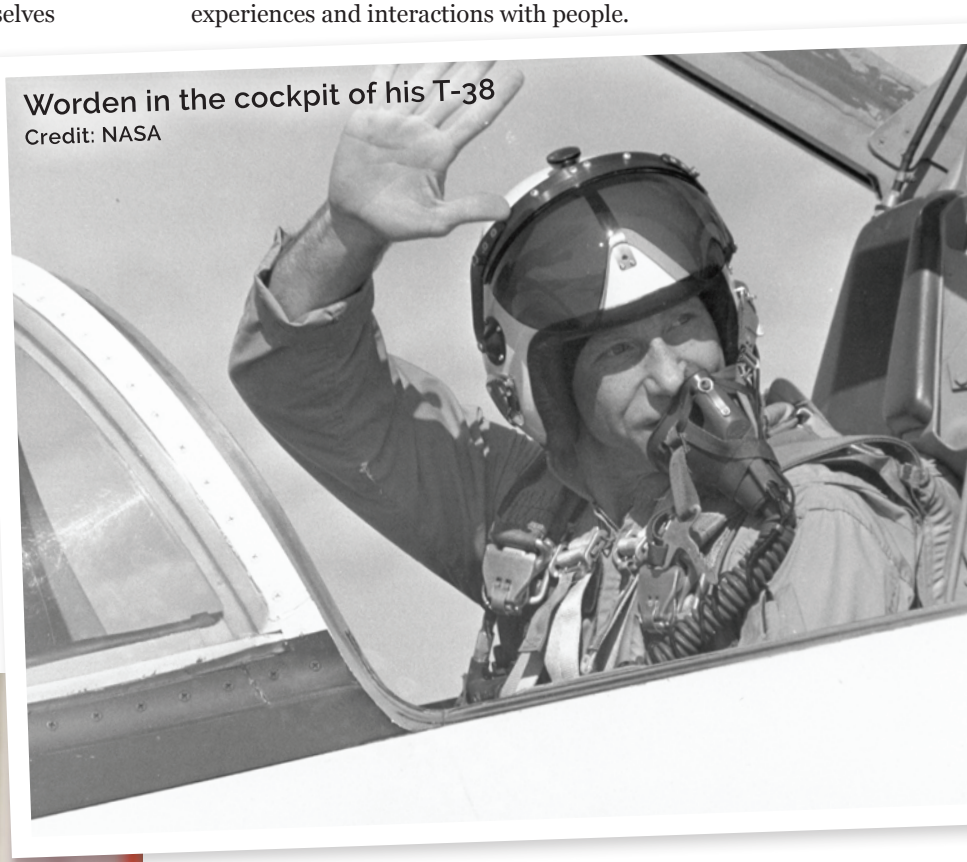
Generosity: generous leaders are grateful, and realize their success is often due in large part because of what others have given to them. They freely give to both people and causes without expectations because they hope for a better world. They live by example, don't ask for anything in return, and truly care and work to enhance the well-being of others.

Trustworthiness: trustworthy leaders are honest and transparent, possess personal integrity, and people are naturally drawn to them. Their behavior is consistent and they provide constant support. While they naturally see the best in other people, they are also willing to "tell it like it is."

Humility: humble leaders are secure in themselves regardless of their popularity and wealth. They are able to put aside their egos, recognize their weaknesses, and seek and acknowledge the input and ideas of others. They are service-oriented and frequently put others before themselves. In the words of Ken Blanchard, the author of *The One Minute Manager*, "People with humility do not think less of themselves; they just think about themselves less."

Resilience: resilient leaders see failure as temporary setbacks. They have grit, remain positive despite adversity or negative outcomes, and find ways to move forward. They are unyielding in the face of hardship and lean on their relationships with others when necessary to overcome obstacles.

No one is perfect, and developing character is a lifelong journey. For eighty-eight years, Al Worden lived a life most of us only dream about. He was a graduate of West Point, an Air Force test pilot, an Apollo astronaut, a global celebrity, and a national hero. Al's character was developed through his many life experiences and interactions with people.



Worden in the cockpit of his T-38
Credit: NASA

Credit: Mark Usciak

His character was *always* on display, regardless of whether anyone was watching. Whether it was taking the time to speak to groups of children, presenting to civic and community groups, having lunch with strangers at a fast-food restaurant, or interacting with people on social media, Al made everyone feel like he was their best friend.

He was never concerned about what people thought of him. While many with his celebrity status work hard to put on a great show and create a perception of how they want people to see them, Al exhibited an authentic care and concern for others, which is why he was adored by so many. In the long term, you can't hide your heart, good or bad, and his was good.

Everywhere Al Worden went, he left a lasting, positive impression. He was exceptionally generous, especially with the one commodity he had the least of: time. He approached life with a thoughtful yet laid-back, almost poetic, mindset. Whether it was meeting the world's wealthiest people, the leaders of nations, famous rock stars, or a few wide-eyed third-graders, Al would frequently respond, "No big deal. There are no strangers in this world, only friends I haven't met yet."

SPACE LAW AND WHY WE NEED IT

Michelle Hanlon,
Legal Scholar, Professor, and Co-Founder of For All Moonkind

The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, colloquially known as the Outer Space Treaty, provides a sovereign-based construct as a framework for the regulation of space activities. Negotiated during the 1950s and 1960s in the magniloquent shadow of the Cold War, the Outer Space Treaty was focused not on the creation of human communities in space, but on the preservation of peace in this boundless frontier whose resources and potential humanity was just beginning to explore.

As its name suggests, the treaty provides principles and not rules, but perhaps more significantly, the principles are offered to govern nations rather than people. While some see this gap as an opportunity to rid our future spacefaring progeny of the bounds of terrestrial legalities, this is not the case. Nestled among the concept of freedom of exploration and use, the prohibition of nuclear weapons and weapons of mass destruction, and multiple exhortations for international cooperation is the statement that countries shall be responsible for the activities of their nationals. The treaty even requires the authorization and continuing supervision of all such activities.

Thus, for six decades, sovereign nations and commercial entities alike have explored and harnessed space to benefit human existence through astonishing advancements in communications, Earth observation satellite technologies and resources, among many others.

But today we stand at a threshold. As we look beyond low Earth orbit, the notion of space resource utilization—the mining of our Moon, asteroids, and other celestial bodies—has moved from dream to prediction. In this regard, the Outer Space Treaty offers us another gap, as Article II of the treaty reads: "Outer space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." Read in conjunction with its statement that the use of outer space "shall be the province of all mankind," this has led some to argue that the benefits of any resource extraction activities must be shared by all people. Others argue that the language of Article II itself implicates only sovereign nations, and not private activity. Both of these arguments are shortsighted.

Even though our first miners may be robotic, humans are a curious, investigative, and migratory species and it is part of our natural instincts to reach for that next frontier, to head to that brighter horizon. To paraphrase the words that Sir Edmund Hillary made immortal, we will do it because it is there. It is inevitable that people will accompany or follow robots to the stars.

At some point, we must recognize that these communities will not, and cannot, be bound by the Outer Space Treaty to terrestrial sovereigns and their norms. National laws and regulations have evolved in response to uniquely terrestrial realities. While fundamental human rights must be preserved—as they travel with the individual—law must be given the opportunity to address the circumstances under which they do so.

As such, the question that faces us on the precipice of our multi-planetary future was best elucidated by Alexander Hamilton: whether societies are "really capable or not, of establishing good government from reflection and choice, or whether they are forever destined to depend, for their political constitutions, on accident and force." It is time to make choices, and claiming that we do not need laws in space is to misunderstand the meaning of law. Yet the framework offered by the Outer Space Treaty focuses on sovereign bonds and responsibilities, so how do we tackle this new chapter of human expansion?

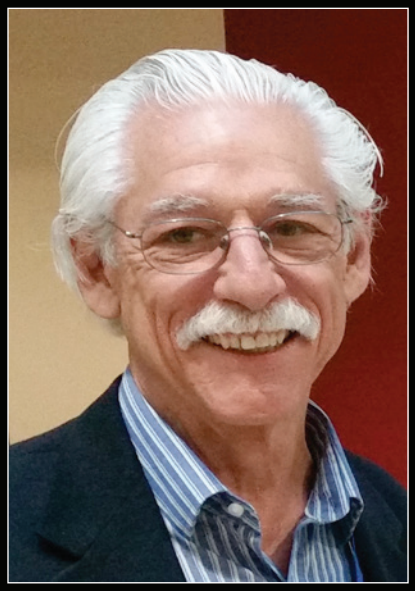
In its purest form, law is a social contract. As Jean-Jacque Rousseau wrote, it is "a form of association which shall defend and protect with the public force the person and property of each associate, and by means of which each, uniting with all, shall obey however only [themselves], and remain as free as before." Likewise, as Rousseau explains, the purest form of the social contract is the family. Children start their lives dependent upon their parents. When this need ceases, the natural bond is dissolved and both the parents and the children become independent, yet they remain united voluntarily, "and the family is maintained only by agreement."

In other words, law is organic. It is a natural tendency for people to enter into these contracts, and that tendency is built around the concept of property. Although an imperfect muse, in part because of the blinders imposed by 18th century society, Rousseau continues to be instructive. He recognized the right of the "first occupant upon any territory" under the following conditions: "first, that the land shall never have been occupied; second, that only such a quantity be occupied as will be necessary for subsistence; third, that it be taken possession of not by any empty ceremony but by labor and cultivation." In turn, those with land occupied as such would unite in a social contract–it is the community that will assure legitimate possession.

The Outer Space Treaty is not at odds with Rousseau; rather, it reaffirms the concept that the exploration and use of space should be free and accessible to all. However, it makes no attempt to provide a governance structure or even a conceptual treatment of property. It is the duty of our generation to build upon the principles set forth by the Outer Space Ttreaty in 1967 and to construct a framework with the benefits of reflection and choice. We need law in space, because it is with law that we will achieve the equality that we all seek, and the Outer Space Treaty itself demands.

Above all else, this law must recognize that we are—or will be—individuals in space, not just nations or corporate entities. Law must offer participants incentive to agree; a social bargain, as opposed to a monocratic canon. It must evolve integrally, its structure must allow for revision, and it must accept that people in space communities have a right to property in some form, as that sense of possession is the basis upon which a contract, an enforceable law, may be achieved. Utilizing the resources of space, and ultimately living and working in space, will provide tangible rewards to the home planet of space pioneers. The law must assure that basic benefits accrue as well to those pioneers themselves.

INTELLECTUAL CONFLICT OVER GOVERNANCE IN SPACE



By Alfred B. Anzaldúa, NSS Executive Vice President

SETTING THE STAGE

The long-standing intellectual struggle taking place in the international arena over the governance of areas beyond national jurisdiction has suddenly intensified. Historically, the region in contention has been the terrestrial seabed, but this controversy is now shifting to outer space.

The disagreement dates back to the 1960s. In general terms, there are two differing groups, but not every person or organization fits neatly into either camp. Nevertheless, assessing the main contenders and their values will help to frame and clarify recent developments, announcements, and publications by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS), China, the United States, the Hague International Space Resources Governance Working Group, the Vancouver Outer Space Institute, the Lunar Development Cooperative Working Group, and other stakeholders and opinion-makers

THE STAKEHOLDERS

These groups are locked in an intense international battle of ideas about governance in space. One side consists mainly of diplomats, lawyers, politicians, organizations, and opinion-makers who favor a top-down international regime or regulatory authority that mandates rules perceived to be equitable for the utilization and sharing of planetary surfaces and space resources. This camp tends to see the Moon Agreement in a favorable light and often holds up the International Seabed Authority (ISA), from Part XI of the U.N. Convention on the Law of the Sea (UNCLOS), as the model for governance in space.

Members of this group began discussions about UNCLOS and the Moon Agreement in the late 1960s and these continued throughout the 1970s, resulting in the 1979 Moon Agreement and the establishment of ISA in 1982 (coming into force as part of UNCLOS in 1994). To this day, no major space power is a party to the Moon Agreement and no commercial mining of seabed minerals has taken place under the authority of ISA—only seafloor sampling.

The other side consists mainly of diplomats, lawyers, politicians, organizations, and opinion-makers who favor governance frameworks that evolve bottom-up from the practices of persons, national and international organizations, private companies, economic sectors, and national governments. Such practices, if widely emulated and not challenged, sometimes become recognized by jurists

as customary international law (CIL) and eventually become codified by international agreements and treaties.

Practices, in this context, consist of not only customary actions or activities by state and non-state actors, but also non-binding soft law, such as national and international rules, guidelines, agreements, principles, standards, proclamations, declarations, executive orders, and court rulings—as well as national legislation and the regulations and activities that flow from that legislation. This side sees the evolution upward from practices into international law as a much more effective way to achieve transparent, equitable, and participatory governance that can adapt to changing circumstances or technologies. They note that a treaty, once negotiated and adopted, becomes a static entity and is almost impossible to amend, thus running the risk of becoming quickly outdated or irrelevant by advances in technology or dramatic changes in societal habits.

It is helpful to think of this bottom-up approach in terms of "subsidiarity," an organizing principle that posits that legal frameworks or rulemaking ought to be handled by or evolve from the lowest or least centralized level, rather than by a central authority. Most people in this group—with some notable exceptions—come from common law countries, examples of which include the United States and United Kingdom. It is generally easier for them to see the law as evolving ground up from case-by-case adjudication.

Members of this group are also distrustful of Article XI of the Moon Agreement and will often cite the difference between the Moon Agreement's declaration that lunar "resources are the common heritage of mankind" versus the Outer Space Treaty (OST) Article I's declaration that outer space and its use is the "province of all mankind." In this regard, it is not a coincidence that Article 136 in UNCLOS Part XI also proclaims that the indicated seabed resources are the "common heritage of mankind," the minerals of which can "only be alienated in accordance with ... the rules, regulations, and procedures of the Authority."

In general, sections within the Moon Agreement's Article XI are also an issue for the bottom-up camp because they repeatedly call for a "regime" to "govern" the exploitation of the natural resources of the Moon. In particular, part of Article XI calls for an international regime to carry out "equitable sharing" of benefits derived from lunar resources and sounds a lot like ISA's regime of forced sharing.

EVOLVING A GOVERNANCE FRAMEWORK

The trajectory for international practices evolving into customary international law (CIL) to be eventually codified by international treaty or convention can take either a very long time or a remarkably short time.

An example of a slow trajectory to a treaty is the case of marine salvage practices that date back to the ancient Phoenician, Greek, and Roman civilizations. These classical maritime practices evolved into customary international law and continued as such until they were codified and expanded by the 1989 International Convention on Salvage, which entered into force in 1996.

A striking example of a fast trajectory from practices through CIL to codification is the chain of events set off by President Truman's 1945 executive order proclaiming that the resources on the continental shelf contiguous to the United States belonged exclusively to the country (the Truman Proclamation). No nation-state objected, and in fact, within five years 30 coastal entities had made similar proclamations, some claiming a 200 nautical mile (322 kilometer) exclusive economic zone (EEZ). By 1950, a country's exclusive resources right to its continental shelf was being recognized as CIL in juridical circles and subsequently codified by the 1958 Convention on the Continental Shelf. UNCLO later upgraded the concept and codified a country's right to a 200 nautical mile (322 kilometer) EEZ in 1982.

In summary, the top-down ISA model currently promoted by the first group took about 30 years to develop and come into force and has yet to produce resource mining of the seabed, whereas the bottom-up practices set off by the Truman Proclamation led to CIL within five years and the first codification within 13 years. Today, resource exploitation of EEZs worldwide touched off by the Truman Proclamation contributes to millions of jobs and many billions of dollars of revenue annually, while commercial resource exploitation under the jurisdiction and control of ISA is non-existent. From these examples, one can currently discern in UNCLOS the result of both top-down and bottom-up governance processes.

Yet this discussion has thus far ignored the elephant in the room. When considering practices leading to CIL and then to codification through a bottom-up evolutionary process, one must distinguish from faulty practices versus best practices like those that evolved from marine salvage customs. Indeed, the careless exploitation of EEZs throughout the world touched off by the Truman Proclamation has also led to oil spills that have harmed not only Earth's environment, but the fishing and tourist industries as well. Moreover, careless government and commercial practices have also led to a space environment contaminated with over 8,000 tons of debris in Earth orbit, and even waste on the Moon's surface.

One may consequently argue that the top-down, international treaty-first process can better safeguard a given area's environment, whether on Earth or in outer space. In the case of the ISA model, however, this claim cannot be proved because commercial seabed mining has yet to take place under ISA jurisdiction and control. Moreover, there is no reason why future governance frameworks in space that evolve from the bottom up cannot be based on best practices by government and private parties. There is, for instance, an idea conceived by Michael Castle-Miller and promoted by the Lunar Development Cooperative Working Group for establishing a lunar development cooperative, designed so that the participants receive more value from the cooperative than it costs them, and this value can only be preserved through best practices that are environmentally sensitive.

Another example of an environmentally sensitive, bottom-up evolutionary framework comes from the Hague International Space Resources Governance Working Group, which in 2019 produced its "Building blocks

for the development of an international framework on space resource activities." Guided by the principle of "adaptive governance," the Hague building blocks call for space resource activities to be "incrementally addressed at the appropriate time on the basis of contemporary technology and practices." Notably, they recommend multiple measures to avoid contaminating the space environment during space resource utilization activities.

INTENSIFICATION BY CHINA AND THE UNITED STATES

Multilateral discussions about the use of space resources inevitably lead to space governance issues, and an important forum for such discussions is the UNCOPUOS Legal Subcommittee (LSC). For instance, the LSC's agenda item 15 is a "General exchange of views on potential legal models for activities in exploration, exploitation, and utilization of space resources." Pursuant to this agenda item, during the 2019 LSC session, several delegates extolled the alleged virtues of the ISA as a model for space governance. Also, last year's main UNCOPUOS session called for informal consultations with UNCOPUOS Member States on the topic of "space resource governance approaches."

The intensifying discussions about space resources (linked to governance) at UNCOPUOS have led to two recent proclamations by spacefaring nations. In November 2019, China proposed establishing a Moon-based special economic zone. Subsequently, President Trump issued Executive Order 13914 in April 2020 reaffirming U.S. support for the 1967 Outer Space Treaty, while specifically refuting the 1979 Moon Agreement. The order also called on the U.S. Secretary of State to seek out like-minded states with which to negotiate joint statements, bilateral and multilateral agreements, and other agreements regarding the safe and sustainable use of space resources. The following May, NASA proposed the Artemis Accords, a legal framework for U.S. agreements with like-minded countries to carry out the mining of lunar water and minerals.

The United States and Luxembourg have both passed domestic laws enabling space resource utilization and have signed a cooperative agreement related to space commerce. Other like-minded states such as Japan, the United Arab Emirates, India, Canada, Australia (despite having ratified the Moon Agreement), and eventually even China (despite its rivalry with the United States) may soon follow suit. Whatever comes out of these proclamations by China and the United States, it is clear that the process in which these and other like-minded states are involved is vibrant and flexible, and does not fit into the top-down, international-treaty-first category.

The position of the Vancouver Outer Space Institute is another matter. The institute (comprised mostly of academics) produced 25 recommendations on space mining. These call for "multilateral negotiations on an international regime for space mining," deemed to include the activation of Article 18 of the Moon Agreement. Even more problematic, the negotiating states are urged to consider "the creation of international governance mechanisms, taking into account models or analogies from other areas such as deep seabed mining," and the "establishment of a mandatory benefits sharing mechanism." There is much more that can be said about the recommendations, both positive and negative. Yet, with its references to the Moon Agreement, deep seabed mining as a model, and with a "mandatory benefits sharing mechanism," the Vancouver Outer Space Institute appears to favor the top-down, international treaty-first group.

A HOPEFUL FUTURE

An international struggle is occurring over the issue of resource utilization and governance in space. The principle contenders, a bottom-up to space governance group with strong ties to industry and the top-down, treaty-first group, are in pitched conflict in their effort to persuade other space stakeholders.

Members of the bottom-up group, nation states (such as the United States and Luxembourg) and civil groups (such as the Lunar Development Cooperative Working Group) are carrying out activities which may eventually bring transparent, participatory, non-authoritarian governance to space. Ultimately, the static, authoritarian model for space governance espoused by the top-down, treaty-first group will be no match for the dynamism and evolutionary adaptive-governance approach of the bottom-up group. It is important for members of organizations such as the National Space Society to have a general grasp of these issues and support the progressive thinking that will allow for the free and wise development of space resources for the betterment of humanity.

FOR FURTHER READING

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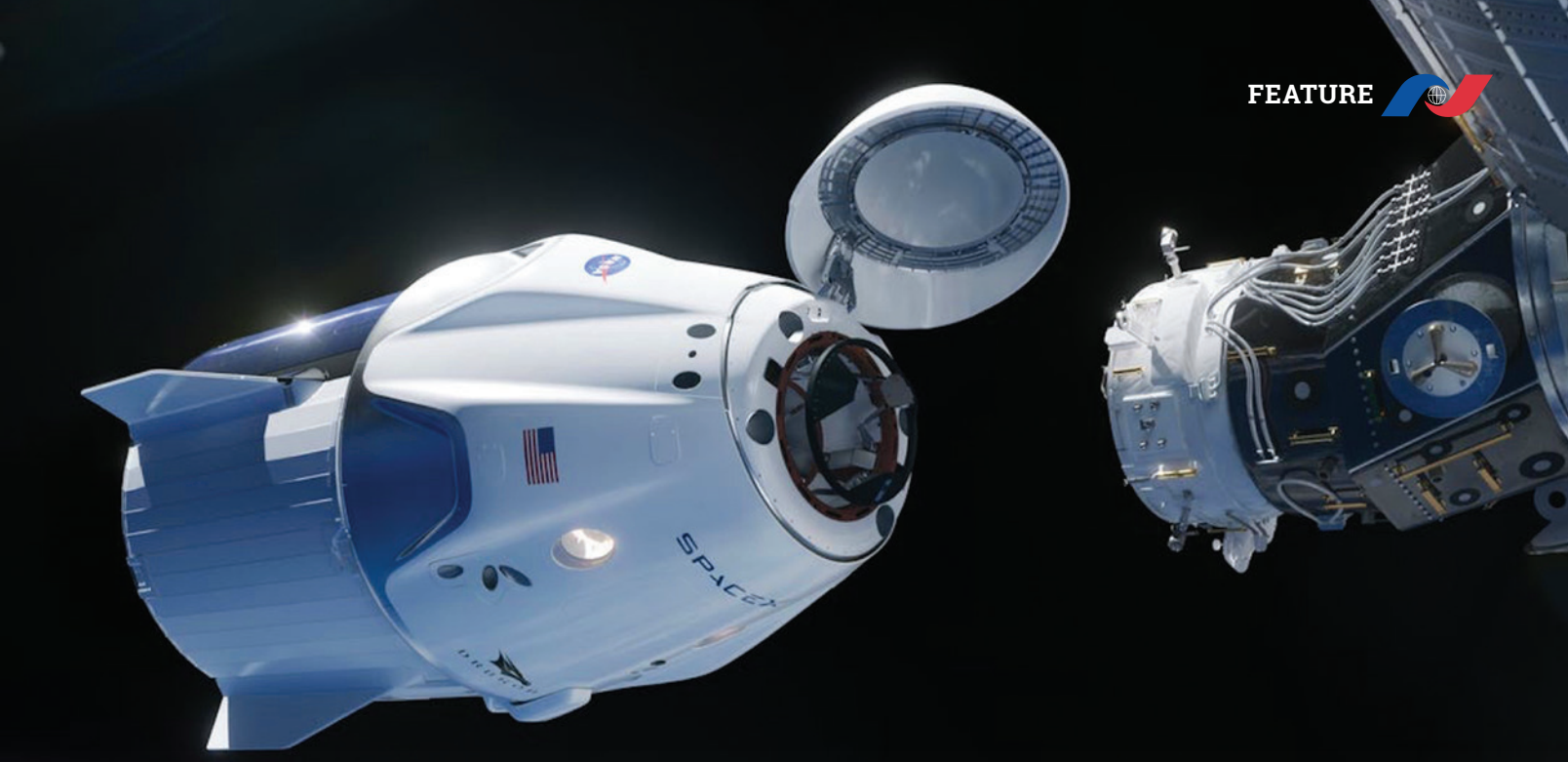


DEMO-2

AMERICA ROARS BACK INTO SPACE

SpaceX's Successful Demo-2 Mission to the ISS

Rod Pyle

On May 30, the United States regained its ability to launch astronauts on domestically-made rockets and spacecraft. At 3:22 p.m. Eastern Daylight Time (EDT), a SpaceX Falcon 9 rocket lofted a Crew Dragon capsule into orbit to begin a 19-hour chase to rendezvous with the International Space Station (ISS).

Aboard the Crew Dragon were NASA astronauts Doug Hurley and Bob Behnken. Both are veteran shuttle astronauts with previous trips to the International Space Station under their belts, and both are married to other astronauts—Hurley to Karen Nyberg and Behnken to K. Megan McArthur (McArthur will be flying on the next Crew Dragon mission).

Behnken first flew in 2008 on STS-123, conducting three spacewalks to assemble a new robotic manipulator arm. He flew again in 2010 for STS-130, completing three more EVAs to assemble the ISS's Tranquility and Cupola modules. Hurley's inaugural flight was in 2009 aboard STS-127, and he was the pilot for the final shuttle flight, STS-135, in 2011. The duo was selected to make the first flight of SpaceX's Crew Dragon in 2018.

After many challenges in the final months prior to liftoff, including stubborn parachutes and some design issues with the Super Draco abort and maneuvering rockets on the capsule, the first launch attempt was scheduled for Wednesday, May 27. However, the fickle Florida weather did not cooperate, and since the launch window was instantaneous, the next attempt was scheduled for the following Saturday.

When Saturday dawned, the weather was still uncertain, with the Air Force giving about 50-50 odds, but the countdown commenced as scheduled. Besides the weather considerations, there were also concerns about the status of the sea off Cape Canaveral. In case of a launch abort, the crew might have to come down

in the nearby Atlantic, making the sea state there a concern. Rough seas could also make things difficult for SpaceX's automated recovery barge, as the company planned to recover the Falcon 9 booster. By 3 p.m., however, conditions had improved and the launch proceeded as planned at 3:22 Eastern Time. Appropriately for this return to human spaceflight on an American rocket and spacecraft, the Kennedy Space Center's pad 39A was the point of departure, just as it was for Apollo 11 and the final shuttle flight, STS-135 (pad 39A is now under long-term lease to SpaceX).

Following the historic launch, NASA administrator Jim Bridenstine commented, "Today, a new era in human spaceflight begins, as we once again launched American astronauts on American rockets from American soil on their way to the International Space Station, our national lab orbiting Earth." He went on to thank the teams at SpaceX and NASA for their hard work, and added, "The launch of this commercial space system designed for humans is a phenomenal demonstration of American excellence and is an important step on our path to expand human exploration to the Moon and Mars."

Musk also commented, saying that the success of the Demo-2 launch was a "dream come true," and echoing Bridenstine's remarks about all the hard work required of both his company and NASA to achieve the milestone. "You can look at this as the results of a hundred thousand people," he noted, including the many suppliers who supported the mission.

Behnken and Hurley were carried into orbit in a flawless performance of the Falcon 9 launcher, with much less jostling apparent on the live in-flight video feed when compared to footage from the space shuttle. The two looked almost relaxed in the roomy Crew Dragon capsule, wearing their bespoke SpaceX pressure suits. The garments were designed by Jose Fernandez, a Hollywood costume designer who also worked on outfits for the Batman, Superman, Iron Man, and Captain America movies.

After the roughly 12-minute ride into orbit, the front protective cover of the Crew Dragon capsule swung open to expose the navigation instrumentation and the docking system, allowing the astronauts to initiate flight tests for this demonstration mission. In the meantime, the Falcon 9 booster made a successful landing on SpaceX's seafaring recovery barge offshore from the launch site.

After about 19 hours, *Endeavour* closed on the ISS and completed docking without mishap at 10:16 a.m. EDT. While the Crew Dragon is capable of fully autonomous flight and docking, the astronauts used the opportunity to test the touchscreen-based control system onboard. The capsule is the third NASA spacecraft to carry the name *Endeavour*, following in the footsteps of the Apollo 15 Command Module and the space shuttle orbiter built after the loss of *Challenger*.

After docking and checking for a secure seal, the hatches of the spacecraft and the ISS were opened. Behnken and Hurley then joined the crew of Expedition 63, NASA astronaut Chris Cassidy and Russian cosmonauts Anatoli Ivanishin and Ivan Vagner. Behnken and Hurley stayed aboard the ISS for just shy of 64 days and spent over 100 hours conducting various experiments. Behnken also participated in four extra vehicular activities with fellow astronaut Chris Cassidy during which they installed new batteries for the aging station and renewed other hardware.

The two astronauts re-boarded the Crew Dragon for their fiery return to Earth on August 2. Flight controllers at SpaceX, joined by a nervous Elon Musk and Gwynne Shotwell, the company's president and

The DEMO-2 Falcon 9 rocket heads for Launch Complex-39A
Credit: NASA

Bob Behnken and Doug Hurley (at right) chat with Elon Musk and Jim Bridenstine (at left) prior to heading to the launch pad (note the sign above the door at rear)
Credit: NASA

A textbook liftoff of the Falcon 9
Credit: SpaceX

CEO, watched along with NASA flight controllers and the public as the spacecraft made a textbook splashdown in the Gulf of Mexico midday, the first water landing of a spacecraft in 45 years.

"Today was a great victory, but it was just the beginning," said NASA administrator Jim Bridenstine after the picture-perfect recovery.

"We are entering a new era of human spaceflight, where NASA is no longer the purchaser, owner and operator of all the hardware," he said. "We are going to be a customer—one customer of many customers in a very robust commercial marketplace for human spaceflight to low-Earth orbit."

The SpaceX system is part of NASA's Commercial Crew program, which has sought to turn over the building and operation of human spaceflight vehicles to the private sector since its initiation in 2011. This has resulted in the development of two systems: SpaceX's Crew Dragon and Boeing's Starliner capsule. The Starliner flew a troubled uncrewed test mission last December, and Boeing is planning a repeat performance soon, prior to scheduling a crewed flight after gaining NASA's approval. Both systems promise to offer large savings over both the space shuttle and the Russian Soyuz systems, with the latter billing out at nearly 90 million dollars per seat and an extended cost of about four billion dollars since 2011. Perhaps more importantly, the Demo-2 flight puts the United States back in the driver's seat of human spaceflight. As Bridenstine said after the successful launch, "As a nation, America is again leading in space."

A RED PLAG

Will Pandemics Threaten Mars Settlements?

John F. Kross

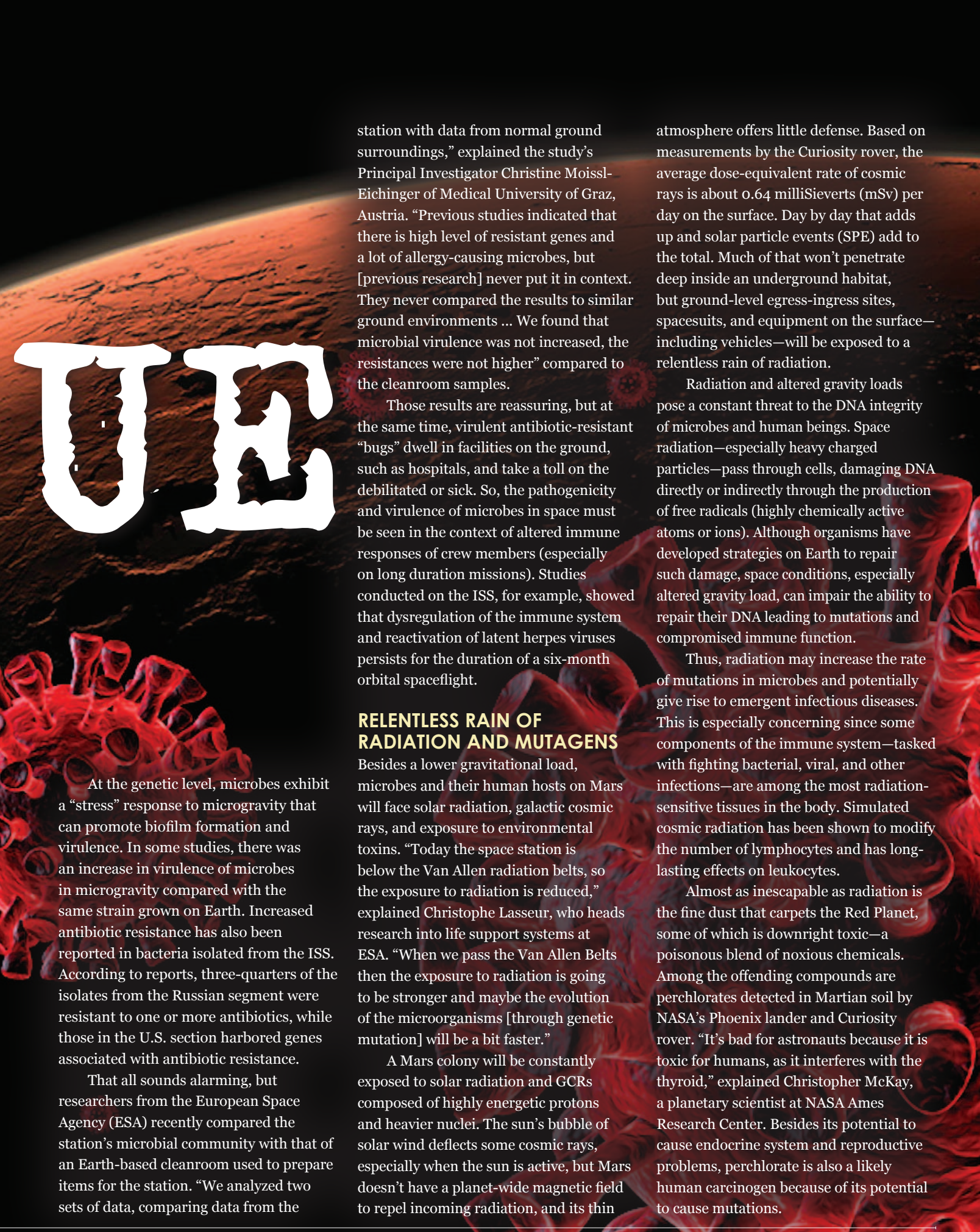
The Space Age isn't immune from disease outbreaks. Apollo crews were quarantined before and after returning from the Moon to limit the exposure and spread of pathogens (terrestrial and otherwise). More recently, NASA and the commercial space industry have responded to COVID-19, the disease caused by the novel coronavirus (SARS-Cov-2), by "social distancing" and other means. As humanity moves out into the solar system, pathogens and their human hosts will square off in unprecedented ways shaped by the environment and technology. Nowhere would an infectious contact be more extraordinary than on Mars.

COLONISTS OF THE MICROSCOPIC KIND

Novel pathogenic and virulent microorganisms can emerge in new or unusual habitats. The SARS-Cov-2 virus, for example, is thought by many researchers to have arisen in "wet markets" from the spillover of an animal coronavirus to humans. The proximity of humans and non-domesticated (exotic) animals in unsanitary conditions can be a breeding ground for a new infectious disease. Conditions there were rife for the emergence of new viruses.

On the surface at least, Mars couldn't be more different from our home planet. The Red Planet is bone-chillingly cold and has a desiccated, chemically oxidizing exterior exposed to galactic cosmic rays (GCRs) and solar wind. Microbes from Earth are unlikely to survive there, but long-term inhabitants of a Mars outpost will live underground protected by several meters of regolith. Inside the habitat, microbes will be at home. Humans and microorganisms will share the same habitat with an atmosphere replenished by a closed environmental control and life support system (ECLSS), while small animals may be reared for food nearby.

Today, the closest analogue to a Mars outpost is the International Space Station (ISS), which is a confined and closed habitat characterized by microgravity. New microorganisms (bacteria, viruses, and fungi) are introduced through the arrival of new crew, cargo, or hardware. A number of different microbes have been isolated onboard the ISS from environmental surfaces, air filters, and even the potable water system. Samples from the Russian segment, for example, contained more than 70 different species (both bacteria and fungi). In the U.S. segment, 318 microbial species were isolated including several human pathogens.



At the genetic level, microbes exhibit a "stress" response to microgravity that can promote biofilm formation and virulence. In some studies, there was an increase in virulence of microbes in microgravity compared with the same strain grown on Earth. Increased antibiotic resistance has also been reported in bacteria isolated from the ISS. According to reports, three-quarters of the isolates from the Russian segment were resistant to one or more antibiotics, while those in the U.S. section harbored genes associated with antibiotic resistance.

That all sounds alarming, but researchers from the European Space Agency (ESA) recently compared the station's microbial community with that of an Earth-based cleanroom used to prepare items for the station. "We analyzed two sets of data, comparing data from the station with data from normal ground surroundings," explained the study's Principal Investigator Christine Moissl-Eichinger of Medical University of Graz, Austria. "Previous studies indicated that there is high level of resistant genes and a lot of allergy-causing microbes, but [previous research] never put it in context. They never compared the results to similar ground environments ... We found that microbial virulence was not increased, the resistances were not higher" compared to the cleanroom samples.

Those results are reassuring, but at the same time, virulent antibiotic-resistant "bugs" dwell in facilities on the ground, such as hospitals, and take a toll on the debilitated or sick. So, the pathogenicity and virulence of microbes in space must be seen in the context of altered immune responses of crew members (especially on long duration missions). Studies conducted on the ISS, for example, showed that dysregulation of the immune system and reactivation of latent herpes viruses persists for the duration of a six-month orbital spaceflight.

RELENTLESS RAIN OF RADIATION AND MUTAGENS

Besides a lower gravitational load, microbes and their human hosts on Mars will face solar radiation, galactic cosmic rays, and exposure to environmental toxins. "Today the space station is below the Van Allen radiation belts, so the exposure to radiation is reduced," explained Christophe Lasseur, who heads research into life support systems at ESA. "When we pass the Van Allen Belts then the exposure to radiation is going to be stronger and maybe the evolution of the microorganisms [through genetic mutation] will be a bit faster."

A Mars colony will be constantly exposed to solar radiation and GCRs composed of highly energetic protons and heavier nuclei. The sun's bubble of solar wind deflects some cosmic rays, especially when the sun is active, but Mars doesn't have a planet-wide magnetic field to repel incoming radiation, and its thin atmosphere offers little defense. Based on measurements by the Curiosity rover, the average dose-equivalent rate of cosmic rays is about 0.64 milliSieverts (mSv) per day on the surface. Day by day that adds up and solar particle events (SPE) add to the total. Much of that won't penetrate deep inside an underground habitat, but ground-level egress-ingress sites, spacesuits, and equipment on the surface—including vehicles—will be exposed to a relentless rain of radiation.

Radiation and altered gravity loads pose a constant threat to the DNA integrity of microbes and human beings. Space radiation—especially heavy charged particles—pass through cells, damaging DNA directly or indirectly through the production of free radicals (highly chemically active atoms or ions). Although organisms have developed strategies on Earth to repair such damage, space conditions, especially altered gravity load, can impair the ability to repair their DNA leading to mutations and compromised immune function.

Thus, radiation may increase the rate of mutations in microbes and potentially give rise to emergent infectious diseases. This is especially concerning since some components of the immune system—tasked with fighting bacterial, viral, and other infections—are among the most radiation-sensitive tissues in the body. Simulated cosmic radiation has been shown to modify the number of lymphocytes and has long-lasting effects on leukocytes.

Almost as inescapable as radiation is the fine dust that carpets the Red Planet, some of which is downright toxic—a poisonous blend of noxious chemicals. Among the offending compounds are perchlorates detected in Martian soil by NASA's Phoenix lander and Curiosity rover. "It's bad for astronauts because it is toxic for humans, as it interferes with the thyroid," explained Christopher McKay, a planetary scientist at NASA Ames Research Center. Besides its potential to cause endocrine system and reproductive problems, perchlorate is also a likely human carcinogen because of its potential to cause mutations.

Hence, microbes will accompany people to Mars with unpredictable changes to pathogenicity and virulence given the unique environmental stressors. They will cohabit with human hosts who have altered immune systems. "We know we will be taking Earth life to Mars with human explorers," explained John Rummel, a former Planetary Protection Officer for NASA. "Some of those organisms ... have negative effects on the International Space Station ... [so] ... Earth-derived organisms will be ... [just as] problematic [on Mars] as they are today."

MARTIAN BIOHAZARDS?

In addition to pathogens transplanted from Earth, the Red Planet might serve up its own microbial biohazards. The odds of extant life on Mars are unknown, but not zero, so an indigenous Martian pathogen cannot be ruled out. Nearly fifty years ago, Carl Sagan foresaw such a possibility, writing that "it is possible that on Mars there are pathogens, organisms which, if transported to the terrestrial environment, might do enormous biological damage—a Martian plague."

Could indigenous Martian microbes cause disease in animals or plants from Earth? According to Rummel, "there has to be coevolution of host and disease ... for true pathogenesis." Genuine pathogens are highly adapted to their hosts through evolution, so the concept of indigenous Mars pathogens infecting Earth lifeforms seems as unlikely as a herpes virus infecting a coconut tree. But at least the virus and tree share the same biological origins, biochemical mechanisms, and building blocks. All bets are off for indigenous Mars pathogens and Earth organisms.

Nevertheless, native Martian microbes might still make proteins and carbohydrates that could spark an immune response. Joshua Lederberg, a Nobel prize-winning molecular biologist, addressed this issue 20 years ago. "On the one hand, how could microbes from Mars be pathogenic for hosts on Earth when so many subtle adaptations are needed," he asked. "On the other hand, microorganisms make little besides proteins and carbohydrates, and the human or other mammalian immune systems typically respond to peptides or carbohydrates produced by invading pathogens ... Although the hypothetical parasite from Mars is not adapted to live in a host from Earth, our immune systems are not equipped to cope with totally alien parasites."

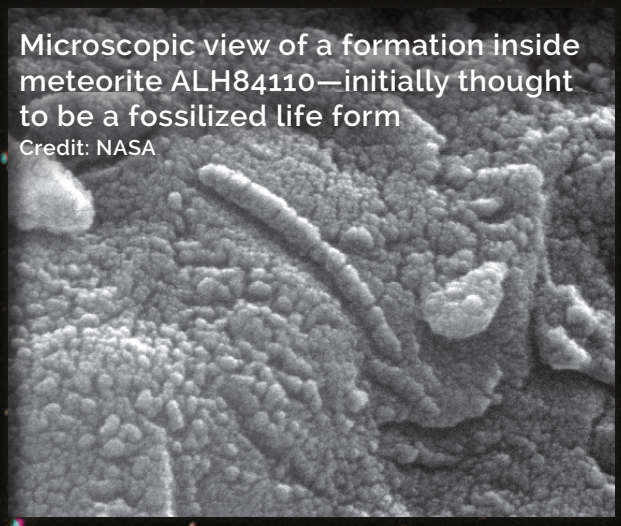
Moreover, Martian pathogens may not be totally alien. Conceivably, Earth and Mars lifeforms might be distant cousins, albeit very distant, given that the two planets are separated only by tens of millions of miles. "There are a number of hypotheses regarding the potential for Mars pathogens, including that they are related to Earth organisms as a result of recurrent asteroid-hosted 'panspermia' events from large impacts on Earth and on Mars," posited Rummel.

So-called panspermia is the hypothesis that life is distributed by space dust, meteoroids, asteroids, and comets carrying microorganisms (and it's not as improbable as it seems). Twenty-five years ago, NASA scientists declared they had spotted possible signs of fossilized microbes in a meteorite ejected from Mars known as ALH84110. That claim sparked a scientific controversy that persists to this day. For his part, McKay contends that "panspermia needs to be taken more seriously. Our current understanding of meteorites from Mars," he adds, "would indicate that any life on Mars, present or past, most likely share a common ancestor with life on Earth. Of course, we do not know for sure and there is still the chance that we will find life ... that originated on Mars independently and separately from life on Earth."

SOCIAL DISTANCING AND MORE

Related or not, human inhabitants on the Red Planet will need strategies to fend off potential pathogenic microbes—from Earth or Mars. Presumably, antibiotics and vaccines targeting Earth-derived pathogens will have a head start given our experience with those interventions on this planet. The efficacy of therapeutic and prophylactic options against indigenous Martian pathogens is a mystery, however.

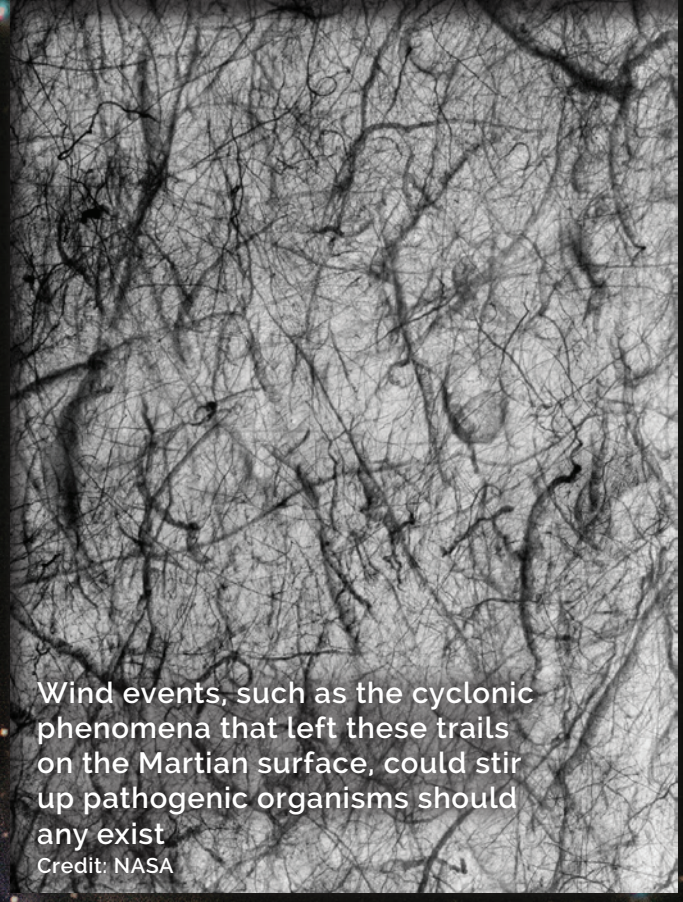
Good hygiene and public health measures will be essential not only for the crew, but also animals raised for food



Microscopic view of a formation inside meteorite ALH84110—initially thought to be a fossilized life form
Credit: NASA

It is uncertain what kind of microbiota—if any—might dwell in Martian soil
Credit: NASA

Sand dunes on Mars seen from orbit. It's likely that any living microscopic organisms would have to be sheltered from radiation by rock overhangs or deep soil—but nobody can be sure
Credit: NASA



Wind events, such as the cyclonic phenomena that left these trails on the Martian surface, could stir up pathogenic organisms should any exist
Credit: NASA

and the environmental control system. "Maintaining a healthy ECLSS is certainly the number one priority," noted Rummel. "If it is a biologically based ECLSS, that goes double. We know that there are plant pathogens on Earth that should be kept out of the habitat, but the most important aspect of this is to keep the plants in a healthful growing environment and depend on their own disease-resistance for at least part of the protection against Earth-origin pathogens."

Monitoring environmental surfaces for troublesome microbes will be a routine part of life in a Martian outpost. The ESA study on the ISS found that some microbes create biofilms or corrosion and others become "technophilic," or technology-loving, growing on metal areas, wiring connection points, and inside equipment. "These technophilic organisms are attacking the surfaces as they struggle to stay alive," Moissl-Eichinger explained.

To minimize microbial growth, ESA researchers have urged future spacefarers to keep surfaces dry and perform periodic sample collection using automated systems to identify microbes and target areas for cleanup. New antimicrobial surface coatings also hold promise. AGXX®, a surface coating consisting of silver and ruthenium, is highly effective against human pathogens and proved its long-term antimicrobial effect on the ISS.

Effective atmosphere filtration systems in the Mars habitat will be needed to decrease the spread of airborne pathogens in recirculated air. Onboard the ISS, high-efficiency particulate air (HEPA)-grade "Bacterial Filter Elements" utilize pleated borosilicate media to control particulates down to 0.3 microns with 99.9 percent efficiency. However, some viruses are less than 0.01 micron in diameter and a finer mesh filter is needed to catch them. It's impossible to predict the dimensions of putative pathogens on Mars so the air filtration system should be as efficient and fine-meshed as possible.

Assuming the air filtration system prevents transmission of pathogens, contaminated areas of a Mars habitat could be isolated from the rest of the outpost using airtight seals in passageways. Centuries-old techniques like quarantine could make a comeback if a settlement has multiple detached habitats or separate groupings of habitats. In a future Mars settlement, Rummel warned, "there will be a desire to ensure that dangerous local contamination isn't spread from place to place."

Separated by months and millions of miles from Earth, settlers on Mars will be on their own in confronting a disease outbreak and a capable and adaptable diagnostic array will be essential. They might need to manufacture their own therapeutics and vaccines until supplies arrive from Earth. Meanwhile, Earth could impose a quarantine on spacecraft returning from Mars. "Once one posits a Mars pathogen, or the potential for a seriously modified Earth organisms on Mars, and couple that with the capability for Earth-Mars-Earth transportation, some sort of health screening and the potential for quarantine will need to be a fundamental part of planning," said Rummel. "Too many cruise ship passengers could tell you that right now!"

If the last few months have taught us anything, it is that global pandemics are not limited to history books. As humanity expands into the solar system, the smallest creatures will feature large in the life and well-being of an outpost. As a species, let us hope we can learn from history and avoid the pandemics that have plagued us on Earth.

A LASTING HOME FOR THE NSS

Melissa Silva

In ancient China during the Han dynasty, the astronomer Zhange Heng wrote that space was infinite, boundless, and "empty and void of substance." People have been trying to fill that space ever since, vying to be the first to launch a man-made object into orbit and cross the invisible boundary that separates Earth's atmosphere from the unknown. That boundary is named after Theodore von Kármán, the Hungarian-American engineer and physicist who calculated the altitude at which our atmosphere no longer supports aeronautical flight: 50 miles, or 83.6 kilometers.

On June 20, 1944, the V-2 rocket became the first object to cross the Kármán line into space. The V-2, part of the *Aggregat* series of rockets designed by Wernher von Braun, was described by a Polish soldier as an "object which ... bore every resemblance to a monstrous torpedo." Those familiar with spaceflight history will be familiar with its characteristic black-and-white checkered livery, liquid-propellent engine, and imposing stature. Several consider the V-2 rocket to represent the beginning of spaceflight; on its first successful test flight in October 1942, Walter Dornberger, the German officer in charge of the Nazi rocket program, declared the day "the first of a new era in transportation, that of space travel."

Just a few years after the V-2 passed the Kármán line and ushered in a new era of innovation and technology, another V-2, this time in the hands of the U.S. Army, was fired from the White Sands Proving Ground in New Mexico and exploded on top of a rocky knoll, leaving a crater nearly 50 feet (15.3 meters) wide and 24 feet (7.3 meters) deep according to local reports. The New Mexico Museum of Space History currently resides near that crater, and its mission is to educate visitors in

the history, science, and technology of space, stressing the role New Mexico has had in the development of the U.S. space program.

"The space program, if you really want to get technical, started in New Mexico," says Sue Taylor, the museum's chief curator. "Going back to Goddard, who moved his lab to Roswell and did his rocket research there, to many of the testings for different aspects of the space program that took place just down the road from us at White Sands Missile Range, the test on the high speed tracks with John Paul Stapp, gauging how many G-forces a human can survive … right down the road from us, [we had] the Operation Paperclip scientists. They stayed in El Paso and they commuted to White Sands for a couple of years and did a lot of work there." Operation Paperclip was the code-name for the program that spirited Wernher von Braun and his associates out of Germany at the end of World War Two.

Taylor has worked in the museum field for 43 years and holds a master's degree in museum education and a bachelor of science in business. She has been instrumental in the proper cataloging and filing of the National Space Society's archives at the museum since accepting her role there in 2015.

It's been Taylor's goal to make the New Mexico Museum of Space History the "go-to space library in the southwest." "You have Houston, you have San Diego Air and Space, but you have nothing in between. I want us to be that 'in between.' We're slowly but surely getting there," she assures. Since 2015, Taylor has outfitted the library with proper shelves and switched over all its holdings to the Library of Congress Classification system, used by most research and academic libraries in the U.S. and other countries. She and her staff are also working diligently to digitize photos and other media so they can then be accessed online through the museum's website. Taylor explains: "the NSS falls squarely into that, where any photographs or anything that they have will be a part of the scanning project as well."

The NSS has had a long-standing relationship with the museum since 2008, though it took several years until it became the official repository of the organization. Pieces in the NSS collection include photographs, books, reports, DVDs, letters, various project notes, and, of course, magazines. "We have all the *Ad Astra* magazines. We have thousands of reams of paper, to the tune of 200 to 300 boxes," says Taylor of the scale of the collection. "We finally got a Bookeye scanner that can scan full newspapers and documents and everything … so we are slowly but surely making inroads, making sure everything is properly cataloged, numbered, and if we go into our catalog system and someone wants to know something, we should be able to pull it up for them." While the museum's library is not a lending library, patrons are welcome to make appointments to visit and use its reference resources.

The museum's impressive holdings offer plenty to those interested in the history of spaceflight and space exploration: complete rockets, including the Little Joe II rocket which tested the Apollo Launch Escape System; the Daisy Track used to study the effects of acceleration, deceleration, and their impacts on the human body; a real Moon rock; and the International Space Hall of Fame, to name just a few.

And the museum is still growing. "We just received, for example, the archives and books that belonged to Ernst Steinhoff. We also got several other collections of some of the operation paperclip scientists that were here—started out at White Sands—and eventually went over to Huntsville, Alabama," says Taylor. "We have Colonel John Paul Stapp's papers … an active oral history program … We also have some scientific books dating back to the late 19th century that deal with the question 'what if man could travel to space?' We have books in Russian, from the Russian space program, and books from German scientists, quite a few of them in German."

Sue Taylor, the New Mexico Museum of Space History's chief curator
Credit: Sue Taylor

Taylor is very passionate about the NSS collection and reports the museum is thrilled to be the organization's repository. "We're very excited that we are the repository for the National Space Society," she says, "because there's so many neat things and interesting subjects and the fact that we're dealing with people that were involved with the Space Race from the get-go. We hear about all these other big names … You hear about the astronauts, you hear about von Braun, and all these others and all that they did. But … how about some of these other people? Just because they're not well-known doesn't mean they didn't contribute mightily to the program, and some still are."

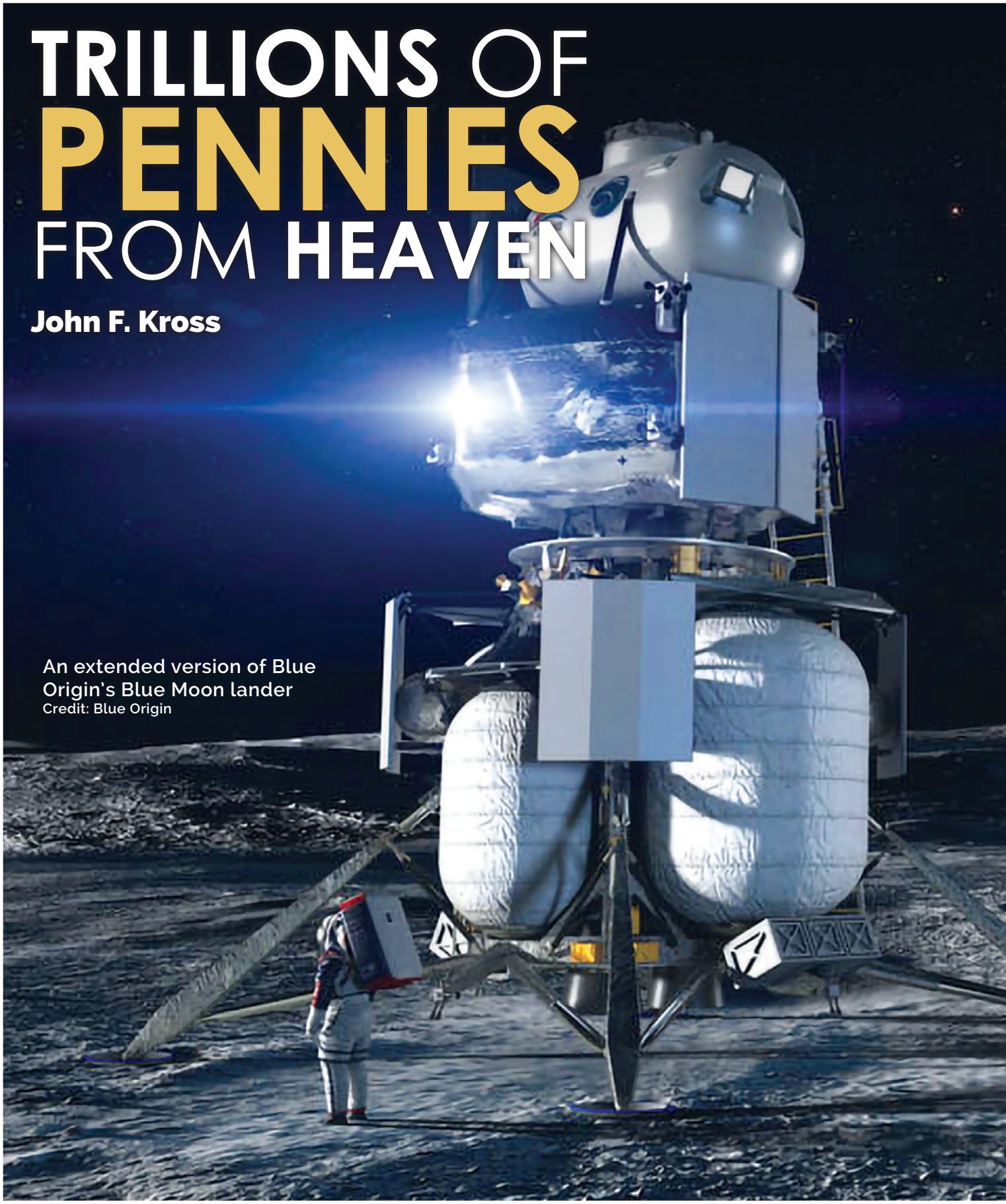
When asked if any piece in the NSS collection stood out to her, Taylor laughed. "They're all fascinating," she replies. "I pick one at random, and it's dealing with a totally different subject than another one I just picked up, but it's all connected. And I think it's that connectedness that really impressed me." Taylor mused they even found letters and minutes from meetings that took place in a nunnery. "When we found that, I couldn't resist, I just said, 'well … we've got nuns in space!'"

Taylor emphasizes that working with the NSS has been a delight: "I'm extremely fortunate to be working with Dale Amon [of the NSS Board of Directors]. He's a wonderful person … and someone I respect greatly. He has done so much already for the NSS archives … One of these days, my assistant and I would love to pay Dale a visit."

In terms of future projects with the NSS, Taylor said there has been talk of finding funding for the organization to send its own intern to the museum, whose sole focus would be cataloging the extensive NSS collection. "There's so much there; I think if I were to measure the linear feet of how many papers we have from the NSS, it would measure upwards of maybe 60, 100 feet, or more," she explains. "It is far from being over."

TRILLIONS OF PENNIES FROM HEAVEN

John F. Kross



An extended version of Blue Origin's Blue Moon lander
Credit: Blue Origin

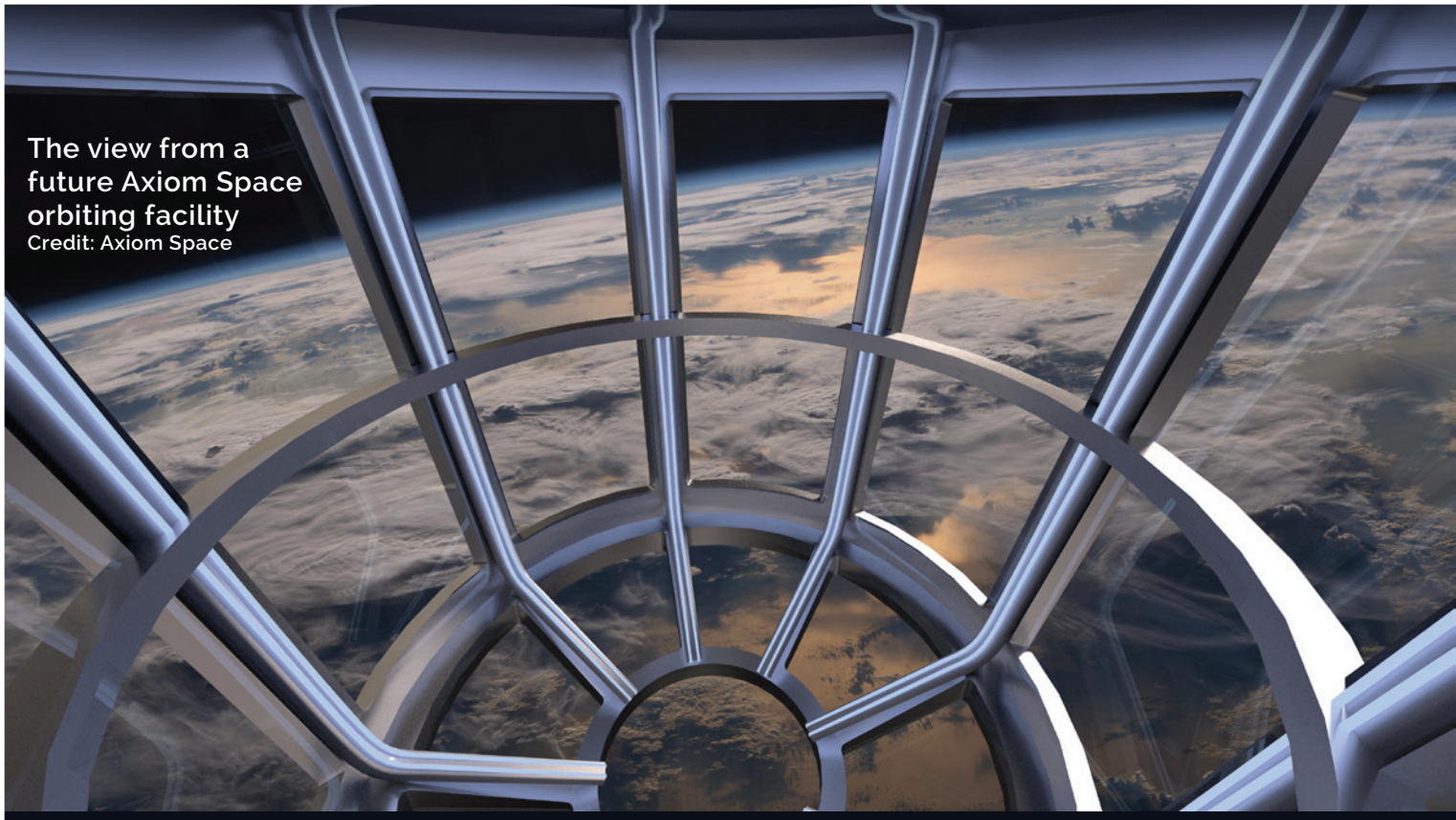
People of a certain age were lucky to have grown up when Technicolor images of needle-nosed rocket ships, rotating space stations, and planetary landscapes graced popular magazines and the silver screen. Cars had fins, hula hoops were in vogue, and private industry was cast as a major player in all things space. For the past 60 years, reality has fallen short of those dreams. However, the confluence of technological innovation, novel commercial models, and entrepreneurship on a cosmic scale point to a more optimistic future.

LIVING AND WORKING IN SPACE

If terrestrial experience is any guide, commercialization will be the key driver of space settlement. Without the ardent support of the private sector, space settlement depends on the vagaries or whims of government, which can change overnight. Fortunately, NASA and a few foresighted lawmakers in Washington, D.C. have in recent years taken steps to promote space commercialization. Months after taking office, the Trump administration announced its Space Policy Directive-1, which promotes commercial partners in the forefront of a "sustainable program [to] return … humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations." The following year, Space Policy Directive-2 directed government agencies and the National Space Council to reevaluate and streamline rules and regulations affecting commercial use of space.

Soon thereafter, Congress called for a human exploration roadmap outlining "an integrated set of exploration, science, and other goals" for NASA's spaceflight program. In response to these directions, the U.S. space agency released a 21-page National Space Exploration Campaign Report. Leveraging commercial space was a major theme throughout the campaign, which listed five strategic goals, starting with transitioning human spaceflight in low Earth orbit (LEO) to commercial providers. Additional objectives ranged from extending long-duration U.S. human spaceflight to lunar orbit and robotic characterization of lunar resources.

The International Space Station (ISS) is the current hub of commercial activity in LEO. Not only is it the destination for Commercial Orbital Transportation Services (COTS)—NASA's program to deliver crew and cargo by private companies—but the orbiting outpost is the focus of commercial research and proof-of-concept manufacturing. The privately held firm Nanoracks has been in the forefront of supplying tools and services to companies, organizations, and governments to conduct commercial activity aboard the ISS and other platforms. Since 2009, more than 50 firms have carried out commercial research and development while a dozen companies have installed 17 commercial facilities on the station.



The view from a future Axiom Space orbiting facility
Credit: Axiom Space

Until recently, however, NASA acted as a "bundler" that controlled commercial access to the station. To uncork that bottleneck, the agency amended its strategy in April 2020 to spur commercialization of LEO. "We are revamping that strategy today," said Doug Loverro, the former Associate Administrator for Human Exploration and Operations Mission Directorate. "As I got a chance to look more and more into this issue it was clear to me that we needed to do more internally."

Loverro started by naming a point-person to advance a unified budget and oversee the Center for the Advancement of Science in Space (CASIS), which manages the ISS research facilities. Prior to these moves, commercial cargo, commercial crew, and CASIS were all independent. Now "we're putting those altogether [to] make sure that they are synergistic," he explained. NASA also adopted a business-focused approach and provided seed money to companies, like Made In Space and Space Tango to mature concepts and stimulate demand.

Additionally, the agency took steps to increase business transparency by publishing a pricing guide for potential users. According to the guide, hiring a current ISS astronaut to work on your business project costs 17,500 dollars per hour. Send your own crewperson and daily fees run 11,250 dollars for life support (and toilet access) plus 22,500 dollars for supplies. Power costs 42 dollars per kilowatt-hour. All these moves are meant to promote business in orbit because, Loverro explained, "we are not the ones who are going to … make LEO commercialization successful, the business world [will]."

ENTER AXIOM SPACE

Instead of the nucleus of commercial operations, NASA aims to be just one of many customers in a "multi-user LEO economy." The most high-profile expression of the agency's commercialization push is granting Axiom Space access to an ISS port for a commercial module that could become the core of a free-flying commercial space station. Earlier this year, the company was awarded a 140 million dollar contract over seven years as part of a public-private partnership with the agency to develop and prove technologies for a future commercial space station.

Axiom Space plans to install the first module on the forward port of the Harmony module, or Node 2, in late 2024. "This is exciting for a couple of reasons," according to Loverro. "Number one, it really shows us that there is private capital … willing to build habitats in space." In addition, Loverro noted that the company has "intentions in the long run to separate that module from the ISS and to make it self-sustaining. This creates the dynamic where NASA and CASIS are no longer the only [ones] looking for business in space. We now have a commercial provider who [is] using their own resources" to find new customers.

The firm was founded in 2016 by aerospace entrepreneur Kam Ghaffarian and former ISS program manager Michael Suffredini. Together, they assembled an industry team that includes makers of pressurized modules on the U.S. segment, Boeing, and Thales Alenia Space of Italy, along with other partners such as rocket engine-builder Intuitive Machines and Maxar Technologies, which NASA tagged to build the Power and Propulsion Element for the lunar Gateway. "The collective experience at Axiom [means] we know firsthand what works and what doesn't in LEO," Suffredini said in a company statement.

The Texas-based company has been tight-lipped on technical details of its proposal, other than saying that the Axiom Segment will eventually consist of the node module plus a research and manufacturing facility, crew habitat, and a "large-windowed" module for Earth observations. When the ISS is retired, the Axiom Segment could detach to become a free-flying commercial outpost powered by its own solar power platform.

The space station already has a commercial module known as BEAM, or Bigelow Expandable Activity Module, built by Bigelow Aerospace and launched aboard a SpaceX cargo Dragon in 2016. BEAM features an innovative inflatable fabric design and, after a thorough checkout, was repurposed as a stowage compartment. The company's founder had long sought to develop commercial space stations—even inking a deal with ULA to launch a much larger expandable B330 module on a Vulcan rocket—but did not bid on the ISS contract. The company laid off its staff in March, citing the coronavirus pandemic.

For its part, Axiom Space is forging ahead, announcing an agreement with SpaceX to buy round-trip missions to the ISS for private astronauts on a commercial Crew Dragon for the bargain price of 55 million dollars. The mission, set for 2021, will carry one professional astronaut and three private passengers to the ISS for a total of 10 days (including eight at the station and two in transit). Axiom Space will provide "turn-key" service, supplying all the training, hardware, life support, crew provisions, safety certifications, and on-orbit operations. In a company statement, Suffredini said, "This history-making flight will represent a watershed moment in the march toward universal and routine access to space … This will be just the first of many missions to the ISS to be completely crewed and managed by Axiom Space—a first for a commercial entity."

SpaceX echoed Axiom Space's zeal for the transport deal as another step in LEO commercialization and a new revenue stream. "Thanks to Axiom and their support from NASA, privately crewed missions will have unprecedented access to the space station, furthering the commercialization of space," said SpaceX President and Chief Operating Officer Gwynne Shotwell. The deal with Axiom came on the heels of a separate agreement with Space Adventures to fly four passengers on a five-day trip aboard a fully autonomous Crew Dragon free-flyer. Launched on a Falcon 9, passengers would have the chance to break the world altitude record for private citizen spaceflight. "This historic mission will forge a path to making spaceflight possible for all people who dream of it," said Shotwell.

An ISS crew inside Bigelow's BEAM module
Credit: NASA

The Bigelow Aerospace B330 expandable orbital module
Credit: Bigelow Aerospace

Loverro had said that he considered the nascent commercial ecosystem in low Earth orbit essential for deeper space exploration. "We are just at the precipice of this great journey," he explained. "It's in NASA's interest and the nation's interest [for] ... this new economy to blossom ... The whole LEO economy is absolutely mandatory for deep space exploration." To realize that goal, however, common-sense statutes and regulations are essential. Hopefully Lovarro's recently named replacement, Kathy Lueders, shares this view.

THE VERY LONG ARM OF THE LAW

Space settlement proponents have long criticized outdated and overly restrictive international space treaties. Uncertainty over the right to recover and use space resources has discouraged commercial companies from taking part in such initiatives. Therefore, in April 2020, President Trump signed an executive order asserting America's right to exploit natural space resources. The order, called "Encouraging International Support for the Recovery and Use of Space Resources," applies to the Moon, Mars, and "other destinations." Future exploration of celestial bodies, it states, will "require partnership with commercial entities to recover and use resources, including water and certain minerals, in outer space."

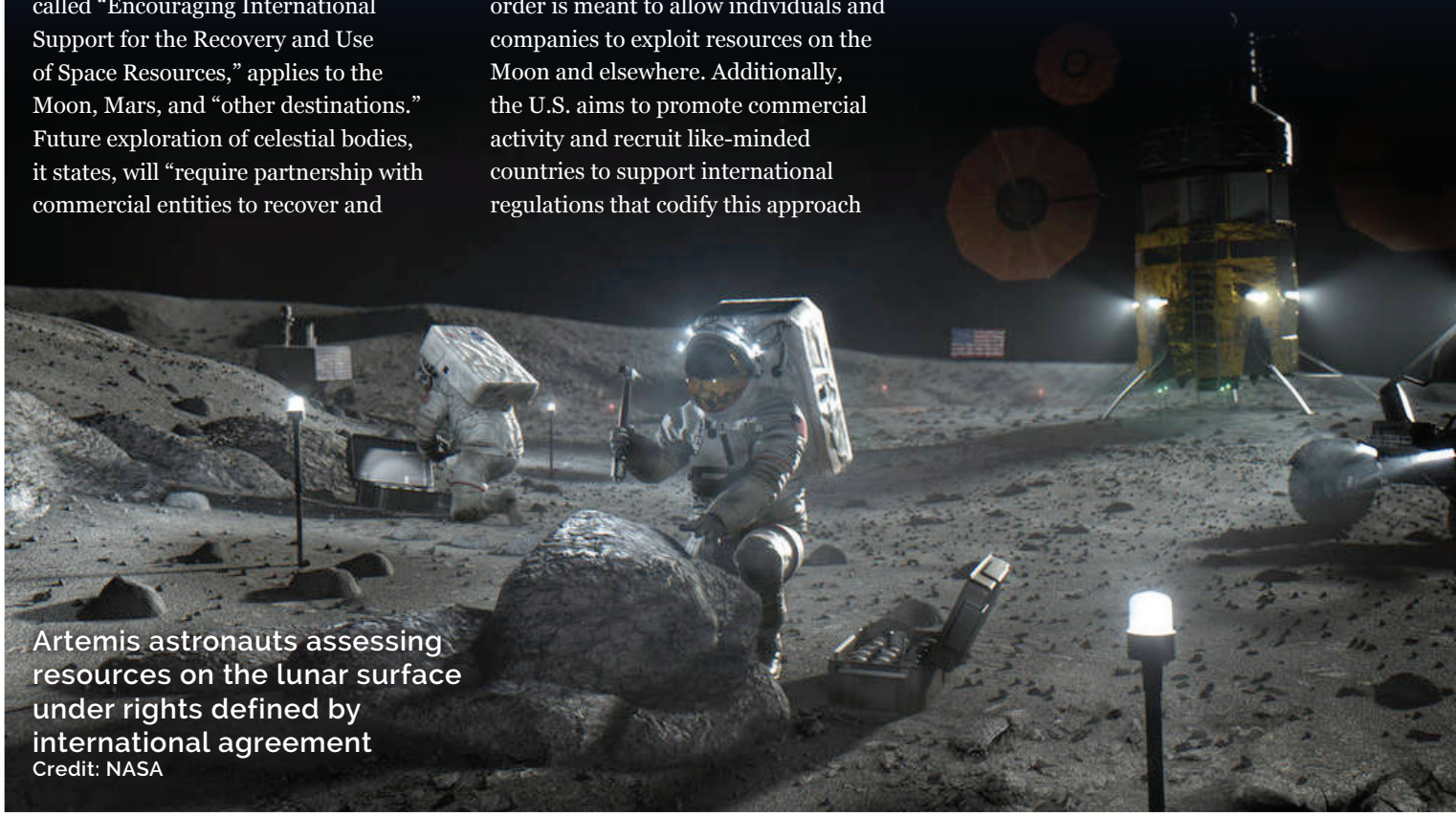
The United States never signed the so-called Moon Agreement (also known as the Moon Treaty) passed by the United Nations in 1979 to regulate the non-scientific use of space resources. However, differences between the Moon Agreement and the 1967 Outer Space Treaty—which the United States and 108 other countries did sign—have created uncertainty about the right to recover and use space resources. The new executive order cuts through the confusion by asserting that "Americans should have the right to engage in commercial exploration, recovery, and use of resources in outer space," and went on to assert that the United States does not view space as a global commons. It stated that the United States will "encourage international support for the public and private recovery and use of resources in outer space, consistent with applicable law."

With this executive action, the United States is not asserting ownership of celestial bodies. Rather, the executive order is meant to allow individuals and companies to exploit resources on the Moon and elsewhere. Additionally, the U.S. aims to promote commercial activity and recruit like-minded countries to support international regulations that codify this approach and head off attempts, by China and others, to establish stealth ownership by state-owned companies.

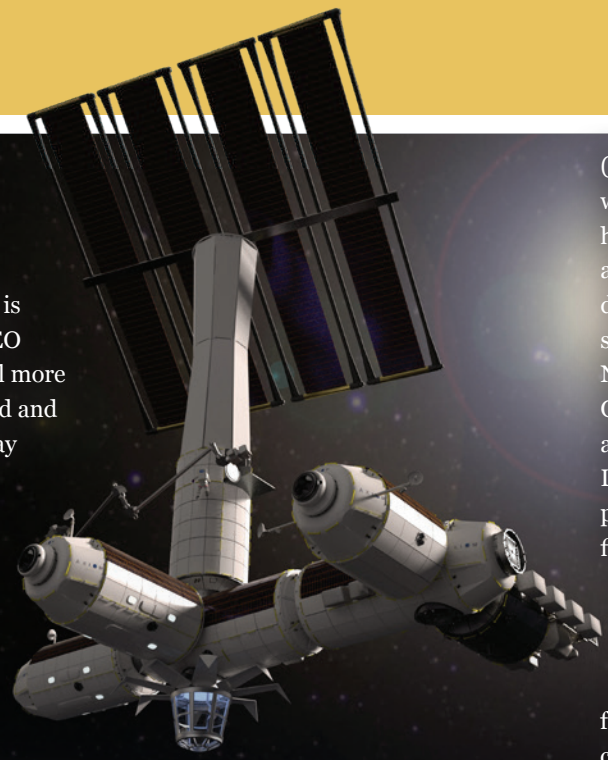
WORKING UNDER A FULL MOON

In the coming decades, geosynchronous orbit will continue to be a prized location as the quantity and scale of space operations increase. New applications will also emerge beyond familiar communications, navigation, and remote sensing. Cislunar space, including the lunar surface, could well become a hub for new uses, such as cargo transport, resource harvesting and processing, energy production, and propellant storage.

The first inklings of the cislunar economy are taking root as NASA leverages its ISS experience with commercial resupply to lunar cargo transportation. In March, the agency selected SpaceX as the first commercial deliverer of supplies to NASA's Gateway in lunar orbit. Under the firm-fixed price



Artemis astronauts assessing resources on the lunar surface under rights defined by international agreement
Credit: NASA



contract, SpaceX will supply multiple launches of a new spacecraft, called Dragon XL, on the company's Falcon Heavy rocket. The cylindrical Dragon XL is a larger variant of the SpaceX's LEO Dragon cargo-carrier and will haul more than five metric tons of pressurized and unpressurized cargo to the Gateway where it will remain docked for up to a year. Dragon XL will add volume for crew activity, storage, and research according to Dan Hartman, the Gateway program manager at NASA's Johnson Space Center.

A thriving cislunar economy will depend on robust infrastructure and commercial lunar cargo transport, and this is the first concrete step in that direction. "We are bringing the innovative thinking of commercial industry into our supply chain … by delivering the supplies [that astronauts] need ahead of time," noted Mark Wiese, Deep Space Logistics manager at NASA's Kennedy Space Center.

NASA's Commercial Lunar Payload Services (CLPS) program is another mile-marker along the commercial highway. So far, the agency has tapped three partners to tote payloads to the Moon's surface via firm fixed-price contracts. Astrobotic and Intuitive Machines are slated for initial deliveries in 2021, and NASA recently announced another CLPS contract with Masten Space Systems to convey payloads to the Moon's south pole in 2022. A few months later, NASA tapped the Astrobotic team again to deliver the Volatiles Investigating Polar Exploration Rover (VIPER) to the lunar south pole. The ice-hunting vehicle is slated to launch in late 2023 as a pathfinder for human missions. "VIPER is going to be a big boost to our efforts to send the first woman and next man to the lunar surface in 2024 through the Artemis program," said NASA chief Jim Bridenstine. As part of the award, Astrobotic will acquire launch vehicle services and integrate VIPER with its Griffin lander. Once on the surface, the half-ton rover will roam for at least 100 Earth-days and probe the polar landscape with a drill and suite of instruments. As part of these public-private partnerships, each CLPS vendor will supply end-to-end commercial payload delivery services from payload integration to landing on the Moon. Enabling technologies such as power generation (solar and RTGs), in-situ resource utilization (ISRU), and cryogenic fluid management might feature in early payloads.

To further stimulate commercialization of cislunar space, the U.S. space agency added five new contractors eligible for the CLPS program, including NewSpace heavyweights Blue Origin and SpaceX. Retail magnate and Blue Origin founder Jeff Bezos has been an outspoken advocate for more public-private partnerships with NASA to transport cargo and people to the Moon's poles, where scientists believe there are abundant water-ice resources. He is also ready to put his own "skin in the game," investing billions to make it happen. Bezos has liquidated large batches of Amazon stock to fund development of his Blue Moon lander, which can reportedly deliver a 14-metric ton (15.4-ton) payload to the lunar surface with the new BE-7 hydrolox engine; he expects strong market demand for a lunar transportation system once development of a permanent human settlement on the Moon begins. In April, NASA announced that teams led by Blue Origin (the "National Team"), Dynetics, and SpaceX were chosen to build Human Landing Systems (HLS) for the Artemis program. The landers will follow the firm fixed price public-private partnership model NASA used for the commercial cargo and commercial crew programs.

Strategies to develop and exploit cislunar space extend beyond a few visionaries and their closely held companies. On their own initiative, some companies like United Launch Alliance (ULA) have brainstormed ideas to bring together entrepreneurs, investors, and governmental entities to create a self-sustaining economy in cislunar space. ULA famously floated its Cislunar 1,000 Vision initiative for a self-sustaining economy that would support 1,000 people living and working in the Earth-Moon system in 25 years.

National space organizations, corporations, and space advocacy groups, including the National Space Society, have all weighed in on the commercialization of space between Earth and the Moon. Beyond the rhetoric, NASA is fostering commercialization by setting ISS commercial use and pricing policy, cultivating an ecosystem for private astronaut missions, and introducing processes for commercial development of LEO destinations. Building infrastructure in LEO will stimulate commercial partnerships and encourage the commercialization of cislunar space, which will ultimately contribute to the economy on Earth. Today, companies are investing their own resources to develop new capabilities in LEO, cislunar space, and the lunar surface, confident that it will spark market demand and generate an economic payoff.

MARTINE ROTHBLATT

Credit: Wikipedia/Andre Chung

NATIONAL SPACE SOCIETY GOVERNOR, PIONEER IN SPACE, GENDER, AND TRANSHUMANISM

Melissa Silva

Satellite radio started as the public's first major alternative to traditional radio broadcasting, sidestepping the limits on content imposed on conventional radio broadcasts. The Federal Communications Commission (FCC) has long prohibited "obscene, indecent, and profane content from being broadcast on the radio or TV." Such laws force station managers to censor some content to avoid being issued a hefty fine. Perhaps the premiere case study for the censorship of radio in the United States is Howard Stern, who racked up over two and a half million dollars in fines issued by the FCC for content it deemed indecent. Stern subsequently signed a five-year deal with Sirius Satellite Radio, a service exempt from the FCC's regulations, setting a new era of radio into motion.

Sirius Satellite Radio officially launched in 2002, founded by David Margolese, Robert Briskman, and Martine Rothblatt. Rothblatt had been a pioneer in satellite communications since her college years and her contributions to the field transformed the landscape of telecommunications. She worked with NASA on projects involving tracking and data relay satellites and launched several communications satellite companies, including quite a few firsts: PanAmSat, an early private international telecommunications satellite project; WorldSpace, the first global satellite radio network for Asia, the Middle East, and Africa; and, of course, Sirius Satellite Radio, the first non-geostationary satellite-to-car broadcasting system.

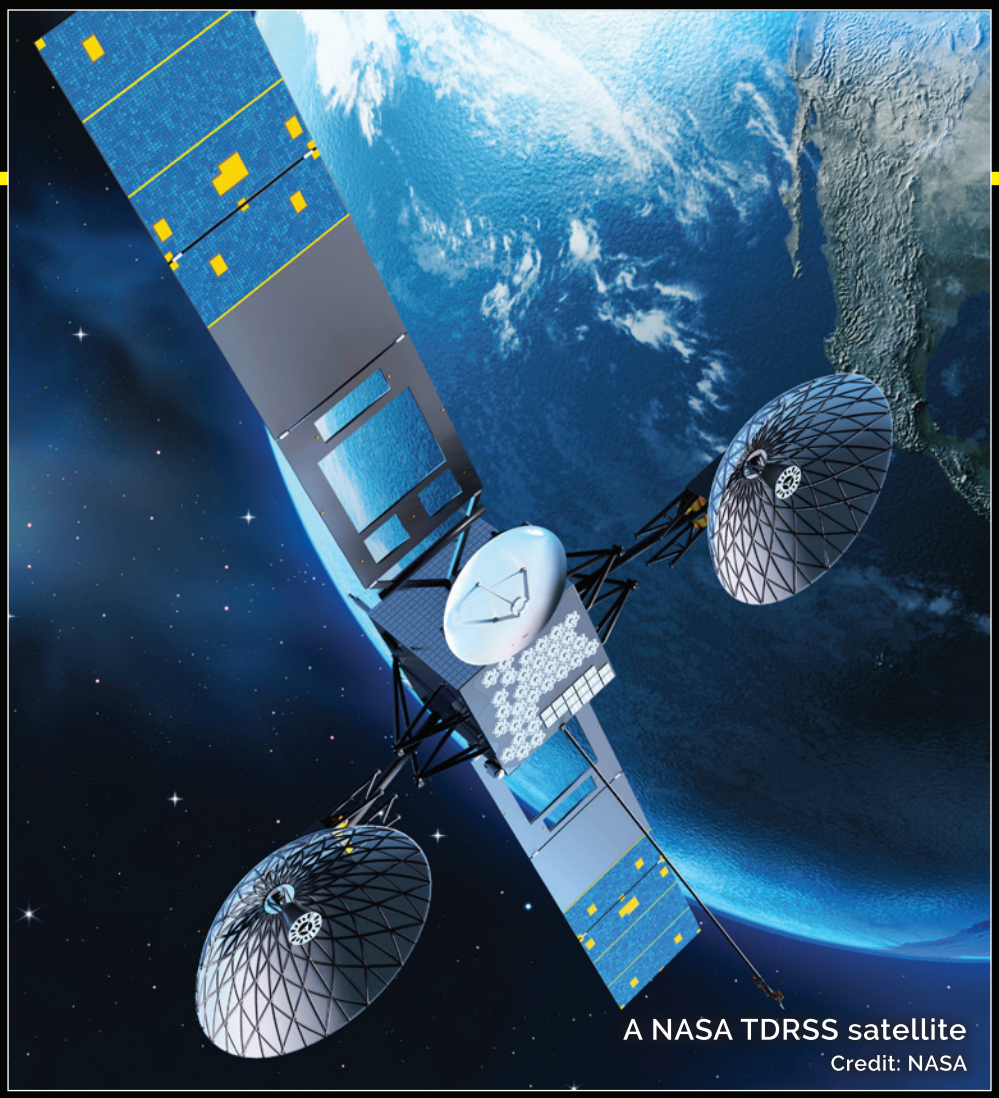
Subsequently, Rothblatt founded a medical biotechnology company, United Therapeutics, and moved into aviation, developing the first electric helicopter. Along with her wife Bina, Rothblatt also founded the Terasem Movement Foundation, composed of three transhumanist organizations whose ultimate goal is to harness nanotechnology and allow people to download their consciousness into a new vessel. The name Terasem was derived from science fiction author Octavia Butler's literature and the fictional

religion featured in many of her works, Earthseed. In Butler's books, Earthseed is a belief system that posits a future for mankind on other celestial bodies.

"It was the first religion I had heard of whose explicit purpose was to move humanity to the stars," said Rothblatt. "The very words Earthseed and its latin cognate Terasem imply that Earth is but a starting point for something that spreads elsewhere. By the end of Butler's *Parable of the Talents*, Earthseed has inspired humanity to live off the planet. So, I wanted to take her literature and make it real-world."

Members of the Terasem community upload biographical information in "mindfiles" and store DNA samples, or "biofiles," for long-term preservation and re-animation using a future consciousness software. These mindfiles will be stored on Terasem servers and backed up in locations around the world. Though seemingly self-serving, the movement's motivation is a unifying one: "The Terasem Movement transcends fear by emphasizing the values of unity and consent. We try to emphasize that nobody should have technology shoved down their throat, and just as fairly, nobody should be prevented from having technology satisfy their soul."

With its foundation staked in sophisticated science and technology, the Terasem Movement has a spiritual element which imbues its tenets with a transcendental quality. "Faith is a tremendously powerful motivator of human behavior," says Rothblatt. "I believe even the most hardcore secular scientists are full of faith, albeit a faith in the validity of a hypothesis that they want to test, or faith that symmetry will help them to discover new mathematical or physical truths. Without such faith, it is hard for people to justify spending substantial portions of their life on something that has an unknown outcome."



A NASA TDRSS satellite
Credit: NASA

It could be said that Rothblatt's venture into biomedicine is a result of such faith. She founded United Therapeutics in 1996 after her daughter was diagnosed with pulmonary arterial hypertension, which was fatal at the time. "I place faith in the power of love to overcome obstacles that would not be overcome in its absence," she explains. "Transhumanism is a faith that it is either God's will, or nature's path, for humans to transcend their evolutionary socio-biological limitations with technology."

Transhumanism traces its roots back to philosophers like Pierre Teilhard de Chardin, a Jesuit priest who was trained as a paleontologist and took part in the discovery of the Peking Man, a group of *Homo erectus* fossil specimens. Professor Brian Swimme says that Chardin "was one of the first scientists to realize that the human and the universe are inseparable. The only universe we know about is a universe that brought forth the human." This philosophy is evident in Rothblatt's work with the Terasem Movement; she believes so-called software-based life will eventually become legalized and part of our social reality within the century.

As for applications in spaceflight, Rothblatt sees the Terasem Movement's mindfile systems as an answer to the perils of space's hostile physical environment. "Because spaceflight poses special risks to biology, from long transits to deadly environments," she explains, "the mindfile system will enable people to undertake these risks without risking killing themselves even if their body gets killed." Rothblatt's involvement in spaceflight stems from her prolific career in telecommunications: "I will never get over the euphoria of launching my first satellites into space on the Ariane 4 rocket from Korou French Guiana, especially the night launches, when it seemed we were putting a new star in the skies."

The Stanford Torus represents one kind of space settlement of the type Rothblatt believes will ultimately allow people to migrate off-Earth
Credit: NASA/Don Davis

Rothblatt is also very outspoken about being transgender and discusses the topic in her book, *From Transgender to Transhuman: A Manifesto on the Freedom of Form*, where she likens gender to a continuum of color, with many shades of male, female, and non-binary. "I think gender would be about the same with digital consciousness as it is today," she says of the meaning of gender in a future where people have been transformed into digital impressions of their consciousness. "Some people would digitally present as the gender they were conditioned into since youth, and others would explore new genders." Among her many honors, Rothblatt serves on the Board of Governors for the NSS.

Telecommunications, Rothblatt predicts, will be ubiquitous in future human spaceflight efforts. She imagines there will be "constellations of communications satellites around other planets and moons, as well as inter-satellite links between constellations that orbit different heavenly bodies." Rothblatt recounts that she first got the idea for SiriusXM when she was visiting a NASA tracking station monitoring the Pioneer 10 mission to Jupiter, and later while helping commercial payloads get onto NASA's Tracking and Data Relay Satellite System.

As for today's issues with storing the vast quantities of data being generated, Rothblatt isn't worried. "Fortunately, storing vast quantities of data is becoming extraordinarily cheap, and thus I expect most data relevant to human space exploration will reside in 'edge cloud' servers that are in space settlements," she explains. "Edge computing will greatly minimize time delays in accessing the world's exponentially growing body of social and scientific information."

Rothblatt's vision of the future of people in space is a hopeful one. "I believe the humanization of space will take a great diversity of forms," she says. "These will include multi-million-person space settlements at L-4 or L-5, on the surfaces of the Moon and Mars, and in ever deeper regions of space. From near-Earth orbit asteroids to the Jovian moons, and out to the Kuiper Belt and even the very distant Oort Cloud, there lies an abundance of extra-planetary chemical wealth beyond that needed to support even hundreds of billions of persons."

At the 2019 International Space Development Conference, Rothblatt proposed a plan based on research by Dr. Gerard K. O'Neill, who believed people could live in large space habitats that could ultimately accommodate greater populations than are currently living on Earth. Rothblatt proposes we can make space settlements happen in our lifetime by using a living extension of a person created by processing a mindfile with a consciousness operating system, that is then mated with a regenerated body. Her detailed proposal is available on her YouTube channel.

Rothblatt is also a proponent of small-group structured approaches to STEM, something that's missing from the American STEM education curriculum, and which has become a perennial issue for educators and politicians. "Fortunately," says Rothblatt, "there is an organization that is capable of taking on this responsibility. It is called FIRST Robotics, an organization of hundreds of thousands of elementary and high school kids, a third of them girls, who compete and cooperate in annual contests to build robots that solve real-world problems. I've been to the FIRST championships, and I've never seen school kids having so much fun with STEM. The U.S. would lead the world in STEM if participation in FIRST Robotics was a required class in all U.S. schools and homeschool programs."

The Terasem Movement offers an alternative solution to the dangers of space and the finality of death, but it also breathes new life into visions of what mankind's future could be. Worlds imagined by Isaac Asimov and Robert Heinlein, of whom Rothblatt is a fan, seem closer than ever before, as we explore our universe and close in on the true extent of our potential. In the words of Octavia Butler: "There is nothing new under the sun, but there are new suns."

A UNIVERSE UNSEEN

REMEMBERING THE COMPTON OBSERVATORY, TWENTY YEARS ON

The Compton Gamma Ray Telescope is deployed during STS-37
Credit: NASA

The Moon as seen by the Compton Gamma Ray Observatory
Credit: NASA

Ben Evans

For a few seconds just before Christmas 1997, a pulse of gamma rays flashed across the sky and left astronomers scratching their heads in bewilderment. Twelve billion light-years away, it appeared brighter than any supernova and seemed to emit more power than our Milky Way galaxy does across centuries. Its source was one of the most energetic events in the known cosmos—a gamma-ray burst—which the media quickly nicknamed "Big Bang 2." For NASA's Compton Gamma Ray Observatory, whose mission to peer into our high-energy celestial backyard ended 20 years ago, the GRB 971214 burst was one of thousands of discoveries which opened human eyes to a universe previously unseen.

Our planet's thick atmosphere guards us against the lethality of gamma rays and studying them has best been done by high-flying balloons or orbiting satellites. Their energies range from 10 kiloelectron volts (keV) to 10 megaelectron volts (MeV) and they originate from astrophysical processes involving the production of high-energy electrons. Since the 1960s, gamma-ray bursts have been seen to flash regularly across space from seemingly random patches of sky and astronomers wondered whether they were related to super-dense neutron stars in our galaxy, or if their origin was more distant and, by extension, far more powerful. Compton would detect gamma rays from the most energetic (and enigmatic) phenomena in the cosmos: solar flares, supernovae, pulsars, quasars, and more exotic possibilities like black holes. In so doing, it promised to uncover clues about the universe at the very dawn of time.

In 1977, NASA announced plans to launch a gamma-ray observatory on the space shuttle. Managed by the Goddard Space Flight Center, it would fly 250 to 300 miles (400 to 482 kilometers) above Earth, high enough to escape the effects of atmospheric drag, yet low enough to avoid interference from the Van Allen radiation belts. After two years in space, it would be retrieved and refuelled by another shuttle crew. In 1980, TRW was picked to build the observatory at its Redondo Beach facility in California, but the road ahead was not smooth and budget cuts threatened cancellation at every turn.

Compton found itself delayed firstly to 1988 and then, after the tragic loss of *Challenger*, into the following decade.

It would carry four scientific instruments. A Burst and Transient Source Experiment (BATSE) from NASA's Marshall Space Flight Center would observe gamma-ray bursts, triangulate their positions using sensors at each corner of the spacecraft, and measure their distribution across the Milky Way and beyond. An Oriented Scintillation Spectrometer Experiment (OSSE) from the Naval Research Laboratory would examine the spectral fingerprints of radioactive elements and investigate novae and supernovae to identify the building blocks of heavy elements. Its four detectors, working in pairs, could observe gamma-ray sources and background radiation, enabling OSSE to spot objects far fainter than BATSE could.

An Imaging Compton Telescope (COMPTEL) instrument from Germany's Max-Planck Institute would generate all-sky maps of moderate-energy gamma rays, measuring their angle of arrival to within a single degree and their energies to within five degrees. Finally, NASA-Goddard's Energetic Gamma Ray Experiment Telescope (EGRET) instrument would map the highest-energy gamma rays, pinpointing their positions to within a fraction of a degree and their energies to within 15 percent. All told, the observatory's spectral range stretched from 20 keV to 30 GeV (gigaelectron volts), with at least 10 times greater sensitivity than any previous instrument.

Compton was the largest and heaviest astronomical payload ever put into space when it launched aboard the space shuttle *Atlantis* on April 5th, 1991. Tipping the scales at 35,000 pounds (15,876 kilograms), it reminded astronaut Jerry Ross of a stout diesel locomotive. Huge accordion-like solar arrays and nickel-cadmium batteries provided electrical power, while specialised coatings, blankets, louvers, radiators, and heaters afforded thermal control. Hydrazine thrusters enabled it to track its celestial targets within an accuracy of half a degree and perform a controlled re-entry at the end of its life.

Two days after launch, astronaut Linda Godwin lifted the observatory out of the payload bay with the shuttle's robotic arm. Its twin solar arrays—which proved troublesome to deploy in ground tests—unfolded perfectly. "I guess everything's downhill from here," crewman Jay Apt remarked to Ross, but his confidence was ill-timed. The next step was to open Compton's high-gain communications antenna, which refused to budge. Godwin tried stopping and starting the motion of the robotic arm to jerk it free, to no avail. Shuttle commander Steve Nagel and pilot Ken Cameron attempted to shake it loose with a burst of *Atlantis*' thrusters. This too proved fruitless.

Only one option remained: Ross and Apt would have to don their spacesuits, go outside, and manually open it. Ross handed Nagel his wedding ring. "Steve," he said, "I'm going to get ready."

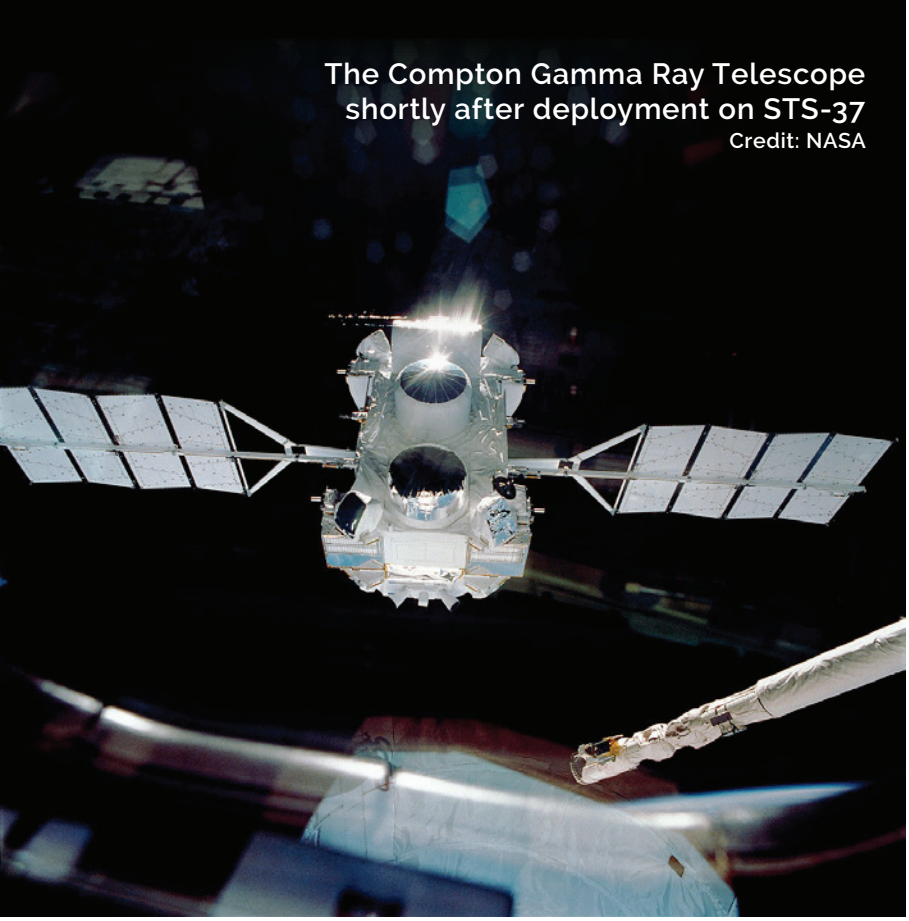
Launching Compton in full working order was crucial. Only months before, the Hubble Space Telescope was heralded as the first of four great observatories to unveil the universe in unrivalled detail but suffered a spherical aberration in its primary optics. Now Compton, the second great observatory, was itself in trouble. With both solar arrays unfurled and a communications antenna jammed, there was no way the shuttle could bring it home for repairs. It had to be fixed in space.

The antenna sat perilously close to Compton's fuel tanks, adding yet another dimension of risk. Ross shook and eventually loosened it. He gave it a couple of hefty pushes and it sprang open. A thermal blanket had somehow gotten snagged on a bolt and the astronaut's intervention took only 17 minutes. Ross' crewmates photographed him grinning excitedly through his spacesuit visor with Compton in the background. For several years after, that picture greeted travellers arriving at Orlando International Airport.

Following a six-week checkout period, the spacecraft began 15 months of all-sky surveys and high-priority observations, after which up to half of its time was devoted to guest astronomers. During its first year, Compton examined emissions from a pair of powerful X-class solar flares, detected a new breed of gamma-ray quasar—some as distant as 10 billion light-years—and in conjunction with Russia's Granat satellite witnessed a huge gamma-ray burst in the Milky Way. In September 1991, the observatory was renamed for Nobel laureate Arthur Holly Compton, who demonstrated the wave/particle nature of electromagnetic radiation and laid the groundwork for modern X-ray and gamma-ray physics.

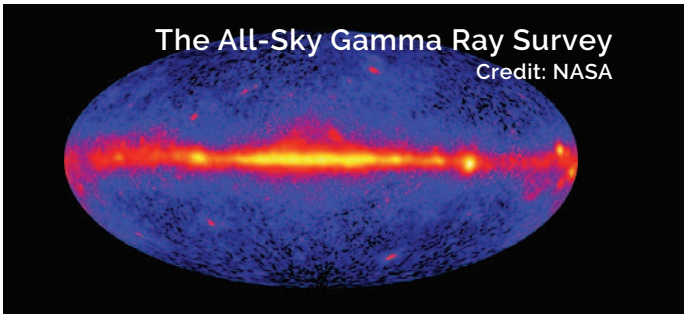
For nine years, Compton produced many astounding discoveries. It found 2,700 gamma-ray bursts (effectively one every day) and its extensive all-sky mapping campaign led to a growing appreciation among astronomers that these phenomena popped up uniformly from all directions, indicating likely origins in the farthest reaches of the universe. One burst in early 1993 earned the moniker "superbowl," because it coincided with the National Football League championship and was 10 times more powerful than anything astronomers had ever seen before.

Compton systematically surveyed the core of the Milky Way and in early 1997 found two "clouds" of antimatter—known as antimatter annihilation radiation—directly above the galactic center. It was theorized that these clouds may have arisen from multiple starbursts, jets of material from a black hole, or perhaps a merger between a pair of neutron stars. One astronomer likened the discovery to finding a new room in a house already occupied since childhood. Elsewhere, it found high concentrations of the radioactive isotopes aluminium-26 and titanium-44 from the Vela and Cassiopeia-A stellar remnants, which gave astronomers a new tool to find the spectral signatures of very ancient and relatively recent supernovae. More than 270 gamma-ray objects were detected, along with an entirely new class of active



The Compton Gamma Ray Telescope shortly after deployment on STS-37
Credit: NASA

Launch of STS-37
Credit: NASA



The All-Sky Gamma Ray Survey
Credit: NASA

galactic nuclei called "blazars," characterised by extremely variable gamma-ray emissions and powerful relativistic jets of matter moving at almost the speed of light.

Closer to home, Compton saw gamma-ray flashes in Earth's upper atmosphere at a rate six times greater than expected. The flashes lasted a few thousandths of a second and tended to be more prevalent over hotspots of high thunderstorm activity near the equator or regions of South America and the East Indies. It was posited that these represent a rare type of electrical discharge in the high stratosphere, and Compton performed joint observations with other satellites and telescopes on the ground.

Despite its success, the spacecraft endured its fair share of technical woes. In March 1992, both of its tape recorders malfunctioned. This proved highly embarrassing for newly inaugurated NASA administrator Dan Goldin, who had previously spent 25 years in charge of TRW's space and technology group that oversaw Compton. Scientific and engineering data was henceforth transmitted directly through NASA's Tracking and Data Relay Satellite (TDRS) system and ground stations. This paid an unexpectedly beneficial dividend, as not only could controllers receive a 24-hour stream of real-time data from the spacecraft, but they could also monitor gamma-ray bursts as they happened. In January 1999, Compton spotted GRB 990123 as it was in progress; ground-based observatories whirred into action within seconds and for the first time captured not only a burst's afterglow, but also its optical flash. One astronomer remarked that if GRB 990123 had occurred in the Milky Way, it would have lit up the entire night sky.

As its mission wore on, atmospheric drag pulled Compton closer to Earth and by September 1993 its altitude was less than 220 miles (350 kilometers). If it descended much lower, its ability to successfully boost itself to a higher orbit would be impaired. Between October and December, a series of thruster firings lifted it to a circular orbit of 280 miles (450 kilometers), effectively lengthening its lifetime by five years. Another orbit boost in June 1997 nudged it a little higher to 320 miles (515 kilometers).

But nothing endures forever, and in April 1999 one of its three stabilizing gyroscopes began to exhibit trouble; it failed the following December. With only two gyroscopes left, and the realization that Compton was too big and bulky to burn up completely in the atmosphere, a plan was set in motion to safely deorbit it. Some astronomers criticised NASA's use of overly conservative odds, but in March 2000 the agency decided that Compton would return to Earth. Four thruster firings over a four-day period brought it tumbling to a fiery end in the small hours of June 4th. Although two-thirds of it burned up, a shower of debris including six heavy aluminium beams and 5,000 titanium bolts rained into an empty stretch of the Pacific Ocean.

In the words of Goddard Space Flight Center director Al Diaz, it was "a bittersweet day" to see the second of NASA's great observatories breathe its last in a torrent of molten metal. Having fundamentally changed our perception of the universe, Compton inspired a new generation of missions, from the Fermi and Swift gamma-ray telescopes to Europe's INTEGRAL. With instrumentation many times more powerful than Compton's own, they have continued to build on its pioneering legacy to reveal the immense variability and dynamism of the gamma-ray sky.

Hawai'i's Contribution

TO THE FUTURE OF SPACE EXPLORATION

Kyla Edison

Hawai'i has longstanding traditions of exploration and the study of the heavens, beginning with the ancient Polynesian navigators. These highly skilled mariners used the movement and position of the stars to determine their location and heading at sea. Today, Hawai'i is a leading center for astronomy research, owing to the near-perfect conditions found at the summit of Maunakea—where high elevation, low humidity, dark skies, and clean air converge to create an ideal environment for studying the mysteries of the universe.

In the last ten years, several major discoveries by Hawai'i-based astronomers have made headlines and paid homage to the Hawaiian tradition of exploration. In 2014, astronomers identified and mapped a massive cluster of some 100,000 galaxies (including the Milky Way). They named this supercluster Laniakea, or immeasurable heaven. More recently, Hawaiian astronomers successfully collaborated in the Event Horizon Telescope project, a world-wide effort to capture the first-ever image of a black hole. When the groundbreaking image was released last year, it was named Pōwehi (which translates to "embellished dark source of unending creation" and is drawn from the ancient Hawaiian creation myth chant, the Kumulipo).

In addition to groundbreaking astronomical discoveries, the islands also represent a global hotspot for planetary science. The images that often come to mind when thinking of Hawai'i are white sandy beaches, clear blue waters, fragrant tropical flowers, and rugged, emerald green mountains. But the island of Hawai'i, also known as the Big Island, is largely composed of massive volcanoes with wide stretches of mangled, black lava fields, and these barren landscapes have been an important focus for planetary scientists and other researchers since the days of NASA's Apollo program. Planetary scientists actually refer to Hawai'i as an "analog site," meaning its volcanic landscapes are geochemically very similar to celestial bodies like the Moon and Mars. This characteristic, coupled with an isolated geography and other-worldly appearance, makes Hawai'i an ideal location to practice living and working beyond Earth.

Between 1965 and 1972, NASA astronauts trained on Hawai'i island in preparation for their missions to the surface of the Moon. They staged geological and other training exercises on all of Hawai'i island's major volcanoes: Hualalai, Mauna Loa, and Maunakea, as well as a variety of craters at the summit of Kīlauea. Visiting the barren, dusty landscapes surrounding these mountains makes it easy to imagine oneself on the surface of a distant planet. These training missions put Hawai'i on the map for lunar and Mars research, and highlighted the scientific value of its stark landscapes.

Today, space agencies and organizations from around the world continue to come to Hawai'i to test spacecraft systems and scientific instruments bound for space. Even human psychology is a focus of serious study to understand group dynamics for deep space missions. The Hawai'i Space Exploration Analog and Simulation (HI-SEAS) habitat on Mauna Loa has served as a study environment for researchers to better understand how groups of people can work together in total

isolation to achieve cohesion and accomplish their goals.

Seated on the slopes of Mauna Loa at about 8,200 feet (2.5 kilometers) in elevation, the HI-SEAS habitat is a dome-shaped enclosure with enough room to house six people. Beginning in 2013, five NASA-funded studies ranging from four months to a year put analog astronauts from around the world in the habitat to live as if they were on Mars. Crews conducted spacewalks in full space suits, surveyed the terrain, and tested instruments, drones, and rovers. Their communications—restricted to email—were delayed to mimic the time it takes transmissions to travel across space. Crewmembers were also challenged to conserve their resources (including food, energy, and water). The studies have gathered data on the technical and social behaviors of human deep-space missions, providing insight into crew dynamics, stress management, morale, and other aspects of psychology and physiology. From 2018, lunar and Mars simulations are being run at the habitat by the International MoonBase Alliance, founded and run by entrepreneur and NSS Governor Henk Rogers, which include the EuroMoonMars initiative led by the European Space Agency.

The fact that Hawaiian volcanic terrain is geochemically very similar to lunar and Martian regolith is another important aspect for planetary science. Hawaiian basalts have been used as regolith simulants for several years. When people begin settling other terrestrial bodies, resource limitations and the costly expense of space travel will make it challenging to carry the resources they need to survive. Astronauts will need to rely on local resources at their destinations to sustain themselves (known as in-situ resource utilization, or ISRU)—essentially, much like the ancient Hawaiians, the practice of living off the land. ISRU will spare the costly expense of transporting materials, and also challenge us to come up with novel ways of building settlements to live and work beyond Earth. Critical resources like oxygen, water propellant, and building materials can theoretically be extracted from the regolith and water deposits found on the Moon and Mars. Hawaiian basalt's analogous properties to regolith make valuable research medium to understand how lunar and Martian materials can be leveraged for ISRU.

The ancient Hawaiians likely could never have imagined that Hawai'i was similar to the Moon or Mars. But it seems only natural that a culture and place so entwined with the stars and exploration would come to support the remarkable evolution in space exploration we are seeing today. The skill, tenacity, and keen observations of the ancient Hawaiians have surely set a precedent for the future of human exploration and the settlement of worlds beyond Earth.

NASA'S NEWEST ROVER IS HEADED TO MARS

THIS TIME WE'RE LOOKING FOR LIFE

Rod Pyle

On July 20, the newest of NASA's fleet of Mars rovers departed for the Red Planet on an Atlas V rocket launching from Cape Canaveral in Florida. This new rover, dubbed Perseverance after a lengthy naming competition among U.S. schoolchildren that garnered 28,000 entries, will be the first machine to search for life on another planet since the Viking Mars landers of the 1970s.

Perseverance is based on the same technological underpinnings as the Curiosity rover that touched down on Mars in 2012 and will use the same elaborate landing system, called Sky Crane. Perseverance looks almost identical to Curiosity—using a common, proven design saves money and enhances reliability—yet the machine is quite different internally. While Curiosity carried an elaborate mini-laboratory within its chassis, Perseverance houses its analytical tools on its robotic arm. This design would have been impossible just a decade ago, but has been made possible by the continuing miniaturization of the technologies required to carry out intensive analytical tasks.

The target landing zone is Jezero Crater, an ancient and geologically complex region where orbital images indicate an 800-foot (243.8-meter) deep lake sat some 3.4 to four billion years ago. In late 2012, the Curiosity rover drilled samples from the floor of its own landing site, Gale Crater, and revealed that the region had been habitable billions of years ago. With this data in hand, scientists and engineers debated the selection of a landing site for Perseverance, and Jezero ultimately won out as the most promising candidate.

Perseverance carries seven primary toolsets for investigating the Martian surface. A number of these are mounted on the rover's robotic arm, and will analyze the chemical, mineral, physical, and organic characteristics of Jezero's rocks and soil, with an emphasis on seeking organic compounds indicative of life, past or present. The camera mast carries the SuperCam—the first zoom-lens camera to travel to Mars—and four separate spectroscopic imagers that will be enhanced by a powerful laser. The laser blasts targets at a distance of up to 20 feet (6.1 meters) and the resulting brief flash of burnt rock allows the spectroscope to identify its elemental composition.

In addition to the on-board instrumentation, Perseverance will "pay it forward" by obtaining soil samples using its newly designed core drill and leaving them behind for a future mission that will bring them back to Earth for analysis. While Curiosity carried a small drill that could obtain tiny samples of powder for analysis, Perseverance's drill is capable of providing actual core samples—about the size of a small cigar—from many inches below the Martian surface. These samples will be stored in hermetically sealed tubes and left at known locations for pickup by a Mars sample recovery rover mission in the future.

The Viking missions of the 1970s also searched for life in the sands of Mars, but the instruments the landers were outfitted with were quite primitive and based on the assumption that Martian microbes would ingest nutrients and release waste gasses in the same way Earthly microbes do. The results of those experiments varied, and while it is generally assumed that they were unsuccessful, this is still hotly debated today. Perseverance's examinations will be much more precise and will provide direct results at the

atomic level, which will be much more accurate than the indirect examinations produced by the Viking missions.

Another facet of this mission—and something entirely new—is the Mars helicopter, named Ingenuity. The small copter will be carried to the planet affixed to the rover, flying free after landing. It is powered by a small solar panel and has two contra-rotating propellers that will provide lift in the very thin Martian atmosphere (about one percent that of Earth). Inspiration will fly above and ahead of the rover at least five times during its month-long minimum lifetime, with each 30-foot (9.1-meter) high flight lasting about three minutes, covering as much as 2,000 feet (609.6 meters) on each hop. This is an experimental system that will be a pathfinder for similar scout craft in the future and is autonomous in operation, coordinating its activities directly with computers on the rover.

The timing of Perseverance's launch was tricky, as the orbit of Mars dictates opportunities only once every two years. Mars missions often slip by this increment, but NASA was determined to make sure this did not not happen to Perseverance. Beset by challenges presented by the COVID-19 pandemic, the space agency worked doggedly—one might say, persevered—to keep the launch on track despite a greatly reduced workforce both at the Jet Propulsion Laboratory, who built and outfitted the rover, and at the Kennedy Space Center, where final preparations for launch were completed.

If all goes according to plan, the new rover should land on Mars on February 18, 2021. Unlike the Viking missions, which orbited Mars before sending the landers down to the surface weeks later, all modern Mars landers are shot to the planet like bullets out of a rifle—the rocket's upper stage sends them off to where Mars will be seven months in the future, and the rover skims the atmosphere to shed speed prior to descending toward the planet. After the heat shield completes its work of protecting the rover and the delicate electronics inside from the searing heat of entry, it drops free and a parachute deploys at supersonic speeds to further slow the spacecraft. Finally, the rover jettisons the aeroshell, and braking rockets on the descent stage fire, slowing it to a hover. The rover's wheels drop from their stowed position, and it is lowered via cables to alight onto the floor of Jezero Crater. At the instant of contact the rover cuts the tethers and the rocket pack flies off to crash in the distance to avoid contaminating the landing site.

Besides its beefy science package, Perseverance also carries a microchip bearing 11 million names the public was invited to submit, as well as a small plaque bearing the Rod of Asclepius—the universally-recognized symbol of the medical profession—to honor the health workers of Earth for their response to the COVID-19 pandemic.

While the competition to name the rover, previously referred to simply as Mars 2020, was an intense one, the choice of Perseverance has turned out to be unusually prescient. Not only have NASA personnel and researchers worldwide had to persevere to get this mission launched on time, but the entire human race has been challenged by the great pandemic of 2020. It's the right name for a mission that provides hope to us all in these difficult times.

Perseverance prior to the sealing of the protective aeroshell. The cruise stage is at top
Credit: NASA/JPL-Caltech

The experimental Mars helicopter Inspiration, the first of its kind
Credit: NASA/JPL-Caltech

THE TANGLED HISTORY OF THE FIGHT FOR WOMEN ASTRONAUTS

From left—Gene Nora Jessen, Wally Funk, Jerrie Cobb, Jerri Truhill, Sarah Rutley, Myrtle Cagle and Bernice Steadman
Credit: NASA

Rebecca Siegel

Between 1960 and 1961, nineteen elite female aviators underwent preliminary astronaut testing to determine their fitness for spaceflight. Thirteen women passed these tests. Their story is tangled, controversial, and often misinterpreted to boost its dramatic narrative. Journalists wax poetic about how these women trained alongside the Mercury 7, but they did not. Headlines proclaim these women were promised the Moon—they were not. Even their popular nickname, the Mercury 13, is misleading, as none were accepted into Project Mercury.

However, the truth is far more compelling than these revisionist versions. It's a tale of ambition, talent, and heartbreak, and a glimpse at an agency with little time to explore anything other than the next step toward its giant leap to the Moon. It's also a story of 13 women who dared to chase an audacious dream.

THE BEGINNING

Much has been made of the early days at NASA, a time so testosterone-soaked that just reflecting on it can give someone a five o'clock shadow. When NASA introduced its first astronauts (the Mercury 7) to the public on April 9, 1959, it was little surprise that they were all male. This was, after all, an era which women were still considered by many to be second class citizens, the vast majority of whom could not attend Ivy League colleges or take out credit cards on their own. The idea of a woman in a spacesuit would have been an extraordinary stretch for a nation accustomed to seeing women attired in high heels and dresses.

The Mercury 7 (Scott Carpenter, John Glenn, Gordon Cooper, Gus Grissom, Wally Schirra, Alan Shepard, and Deke Slayton) had been chosen through a rigorous screening process that began with a list of qualifications compiled by NASA's astronaut selection committee. Ideal candidates were to meet the following:

- Be 5'11" or under,
- Weigh 180 pounds (about 80 kilograms) or less,
- Hold a college degree in engineering (or the equivalent),
- Be a graduate of military test pilot school,
- Have piloting experience in jets,
- And maintain a flight log with at least 1,500 hours.

Those who made it through this initial filter then had to go through a set of medical and psychological tests designed to identify aviators with the best physical and mental conditioning for the predicted stresses of spaceflight. An Air Force general half joked that NASA was looking for "a group of ordinary supermen."

The seven men left standing at the end of the process would be launched not just into space, but also fame. Their rise was swift and made all the more precipitous by the fact that they were the kind of hero the nation was ready to embrace. In addition to having what author Tom Wolfe would later coin "the right stuff" (a rare combination of skills and traits ideally suited for the perils of such supersonic careers), the first astronauts also looked the part. They were handsome, clean cut, fit, white, and entirely male.

But while America wrapped the Mercury 7 in its warm embrace, two men involved in their selection—the head of NASA's Life Sciences committee, Dr. Randy Lovelace, and Air Force Brig. Gen. Donald Flickinger—wondered about women astronauts. NASA's initial astronaut requirements were gender exclusive, as women couldn't fly in the military. They hadn't been allowed to do so since the dissolution of the Women's Air Force Service Pilots (WASPs) back in 1944, and that meant they couldn't meet either the military test flight or jet flight requirements. Despite this, Lovelace and Flickinger allowed their curiosity about women astronauts to grow.

WOMEN TEST SUBJECTS

The idea had practical roots. If someone could show that women had "the right stuff," then they might make preferable astronauts for the budding space agency's early missions. Most women weighed less than men, and would consume less oxygen, food, and liquid during flights. This could mean a significantly lighter payload for missions, something that would surely appeal to NASA's rocket scientists.

Beyond the weight issue, women appeared to be more physically amenable to spaceflight. They had fewer heart attacks, and medical research suggested they might fare better in the predicted conditions of spaceflight. Also, amidst worries about the effects of space radiation, a woman's physical makeup—with her reproductive organs shielded inside her abdomen—seemed preferable to that of a man.

This information suggested that women might make good astronauts, but were they up to the task? Flickinger and Lovelace decided to find out, beginning with a world-record holding female aviator named Jerrie Cobb.

Jerrie Cobb in the MASTIF flight simulator
Credit: NASA

JERRIE COBB

Cobb fit some of NASA's astronaut requirements. She was 28 years old, had over 7,000 hours in her flight log, weighed 125 pounds (57 kilograms), and stood at 5'7". She had been named the National Pilots Association Pilot of the Year as well as the 1959 Woman of the Year in Aviation. When Lovelace asked her to become a "test subject for the first research on women as astronauts," Cobb had agreed without hesitation.

The research had a rocky start, as Flickinger's colleagues at the Air Research Development Command caught wind of his "girl astronaut program" and voted for its cancellation. In her book, *Right Stuff, Wrong Sex*, historian Margaret Weitekamp reveals why. Flickinger's colleagues had come to the conclusion that there was "too little to learn of value to Air Force Medical interests and too big a chance of adverse publicity" to justify the project. Just like that, Flickinger was out.

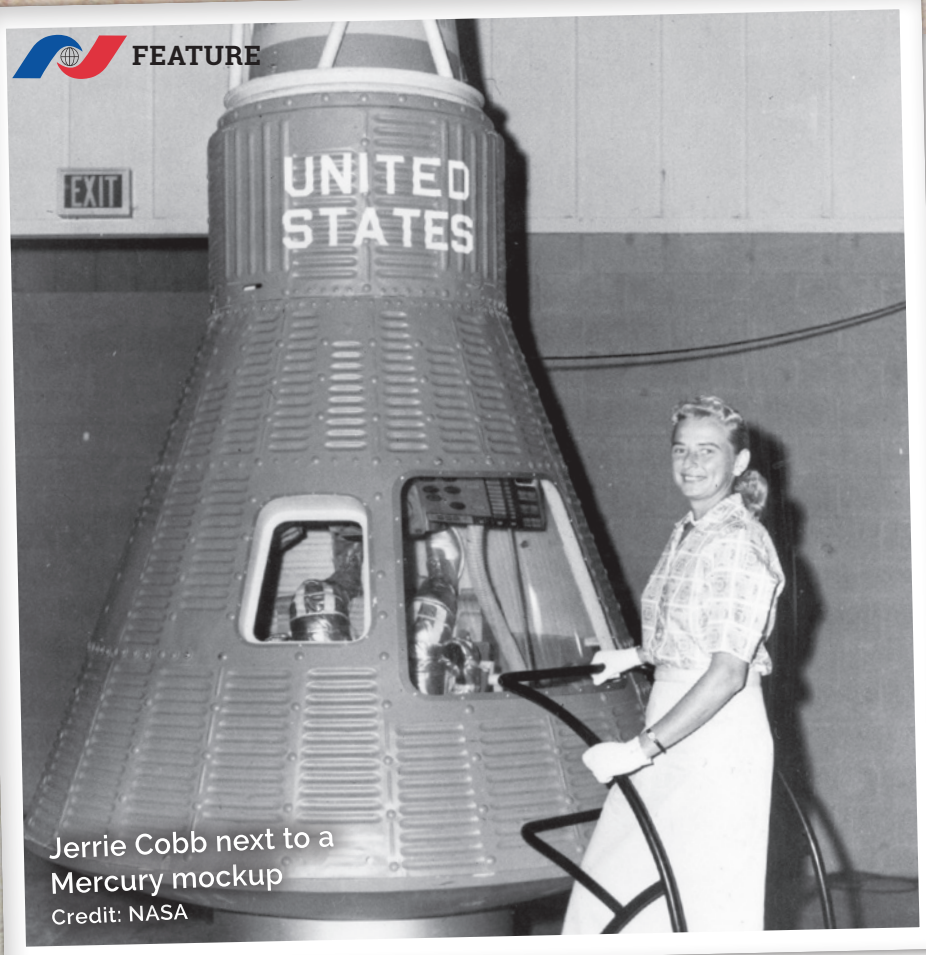
Lovelace took over, supervising as Cobb began her Project Mercury astronaut tests in February of 1960. She endured the same invasive, uncomfortable, and embarrassing procedures that the men had gritted their teeth through. She proved her psychological stability through lengthy interviews, just like they had. She showed her stuff in an altitude chamber and mastered NASA's MASTIF trainer, the gimbal rig that tumbled astronaut trainees on three axes at once.

Some of Cobb's tests were different from what the men had experienced. For example, while they had completed their isolation tests by sitting in a dim room for a couple of hours, Cobb underwent a relatively new sensory deprivation experience. She floated in a pool of warm water in a completely black and silent room. No previous test subject had managed to stay in the tank for longer than six and a half hours, but Cobb lasted nine hours and 40 minutes.

A supervising physician was impressed, explaining that "Miss Jerrie Cobb not only possesses no significant liabilities, but also possesses several exceptional qualities and capabilities for serving on special missions in astronautics." Cobb had "the right stuff" in spades, and Lovelace wondered if other women might too.

JACKIE COCHRAN AND THE REMAINING 12 WOMEN

Lovelace could not fund an extensive testing program on his own, so he



Jerrie Cobb next to a Mercury mockup
Credit: NASA

reached out to an old friend and leader in American aviation, Jackie Cochran. Cochran had run the WASPs during World War Two and looked forward to running another large-scale female aviation program. She agreed to fund Lovelace's women astronaut research project.

From January through August of 1961, eighteen female pilots traveled to the Lovelace Medical Clinic for their own Project Mercury astronaut tests. Jackie Cochran also attempted to take some of the tests, but was refused by Lovelace out of concern for her health and advanced age. None of the women could meet NASA's astronaut requirements. However, there was reason to suspect that these qualifications weren't as crucial as they appeared.

Three of the Mercury astronauts, John Glenn, Scott Carpenter, and Wally Schirra, hadn't actually met the requirements either. Glenn and Carpenter didn't have college degrees at the time of their selection, and Schirra was five pounds over the weight limit. This made it seem as though the agency might bend the rules a bit for the right pilots.

Many of the women maintained impressive flight logs. Jan Dietrich, a pilot out of California, had over 8,000 hours in her log. Irene Leverton, a Chicago-born pilot had even more: a staggering 9,000 flight hours. In comparison, John Glenn, who was the most experienced pilot accepted into Project Mercury, had just 5,100 hours in his log at the time of his testing.

The women's flight logs were important because they were a record of obstacles overcome and prejudices tackled. Women pilots were relatively rare and faced plenty of opposition from their peers. Jerrie Cobb had been told repeatedly that flying was "man's work," and once even listened to a hiring manager lecture her that he couldn't "expect our passengers to fly with a girl copilot. They're already scared of flying, and a girl in the cockpit will frighten them even more." Given this attitude toward their work, it is significant that these women were able to amass such extraordinary numbers in their logs.

By the autumn of 1961, thirteen women pilots added a new item to their resumes. Each had passed their first round of astronaut tests with "no medical reservations." These women were:

Myrtle Cagle
Jerrie Cobb
Janet Dietrich
Marion Dietrich
Wally Funk
Sarah Gorelick Ratley
Janey Hart
Jean Hixson
Rhea Hurrle
Irene Leverton
Jerri Sloan
Bernice Steadman
Gene Nora Stumbough

Sixty eight percent of the female test subjects had been given the highest possible evaluation. In comparison, only fifty six percent of the male astronaut tests subjects had completed their tests with the same endorsement. Lovelace Clinic physician Donald Kilgore was impressed, saying, "These women showed they could take the stresses of spaceflight better than the men. They generally outdid the men."

MOVING FORWARD

Medical exams complete, Lovelace wanted the women to take more tests to paint a fuller picture of their competency for spaceflight. Wally Funk and Rhea Hurrle flew to Oklahoma City, Oklahoma to complete their psychological exams (including the isolation test). Like Cobb, Funk and Hurrle passed with flying colors. Hurrle managed an impressive 10 hours in the isolation tank. Funk did even better, staying in the tank for 10 hours and 30 minutes. Both women left with ringing endorsements from medical staff on their astronaut candidacy.

In the fall of 1961, Lovelace invited his test subjects to the Naval School of Aviation Medicine in Pensacola, Florida for additional testing. This would be the first time they tested as a group, and also the first time their testing took on a formal, officially-sanctioned feel. Pensacola leadership asked NASA if the space agency had a requirement for this time consuming and expensive research project.

NASA had never supported Lovelace's women astronaut research. In 1960, the agency had released a statement saying that it "never had a plan to put a woman in space, it doesn't have one today and it doesn't expect to have one in the foreseeable future." Press had begun to swirl around Jerrie Cobb and her dreams of spaceflight. It was an unwelcome distraction for an agency nearly overwhelmed with the task of landing a human on the Moon before 1970.

When the Navy asked about NASA's requirement for Lovelace's project, it was tantamount to asking for the agency's written approval. They swiftly declined, and Lovelace sent a telegram to the women:

> *"Regret to advise arrangements at Pensacola cancelled, probably will not be possible to carry out this part of program."*

The program was over.

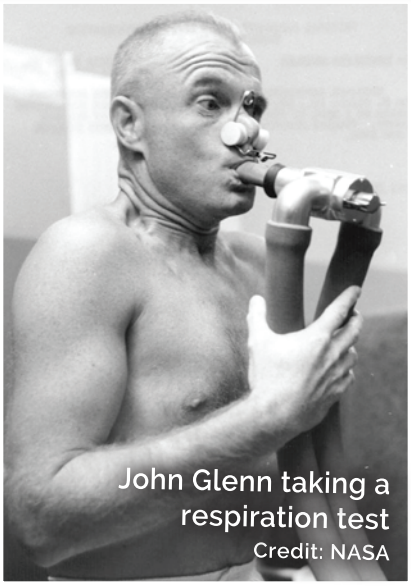
FALLOUT

Jerrie Cobb refused to accept the news. She fought to bring the program back up to speed, arguing that NASA's astronaut requirements were unfair to women. In the spring of 1962, Cobb teamed up with another astronaut test subject, Janey Hart, to raise the stakes. The pair met with Vice President Lyndon Johnson, the head of President Kennedy's Space Council, with their problem: they wanted to continue testing women for astronaut candidacy.

Johnson's secretary was hopeful that he'd side with the women. She drafted a letter to Administrator James Webb for the vice president to sign, questioning NASA's exclusion of women astronauts, and left it on his desk. Johnson was polite yet dismissive; he wasn't interested. He scrawled a note to his secretary at the bottom of her letter: "Let's stop this now!"

TAKING THE FIGHT TO CONGRESS

Cobb and Hart kept at it, but they bumped into the same message about their astronaut dreams again and again. As they could not meet NASA's requirements of jet flight and military test flight, they could not be considered. The women argued that these requirements were discriminatory because women were prevented from meeting them. In July 1962, Cobb and Hart brought their fight for spaceflight to the House of Representatives, where a subcommittee within the Committee on Science and Astronautics held a special hearing to determine whether NASA had discriminated against women.



John Glenn taking a respiration test
Credit: NASA

The hearing was a flop. Testimonies from Deputy Associate Administrator for Manned Space Flight George Low and astronauts Scott Carpenter and John Glenn echoed the assertion that the astronaut requirements were a necessary screening tool. Jet piloting and test flight were good practice for spaceflight, and someone who had excelled in those fields would likely do well as an astronaut. Glenn didn't seem impressed by the fact that 13 women had passed their preliminary tests. He said, "the tests mainly are run to see if there is anything wrong with a person physically ... We have the Washington Redskins football team. My mother could probably pass the physical exam they give preseason for the Redskins, but I doubt if she could play too many games for them." Glenn didn't argue that women shouldn't be in space, but suggested that their exclusion was simply a "fact of our social order."

Jackie Cochran made an appearance, too, now arguing against Lovelace's program. She had decided that a larger, more in-depth study was needed to determine the viability of women astronauts. This would take time, and Cochran assured the group that it would be better to wait until women astronaut candidacy had been properly studied rather than to rush and "take a chance on having women fall flat on their faces."

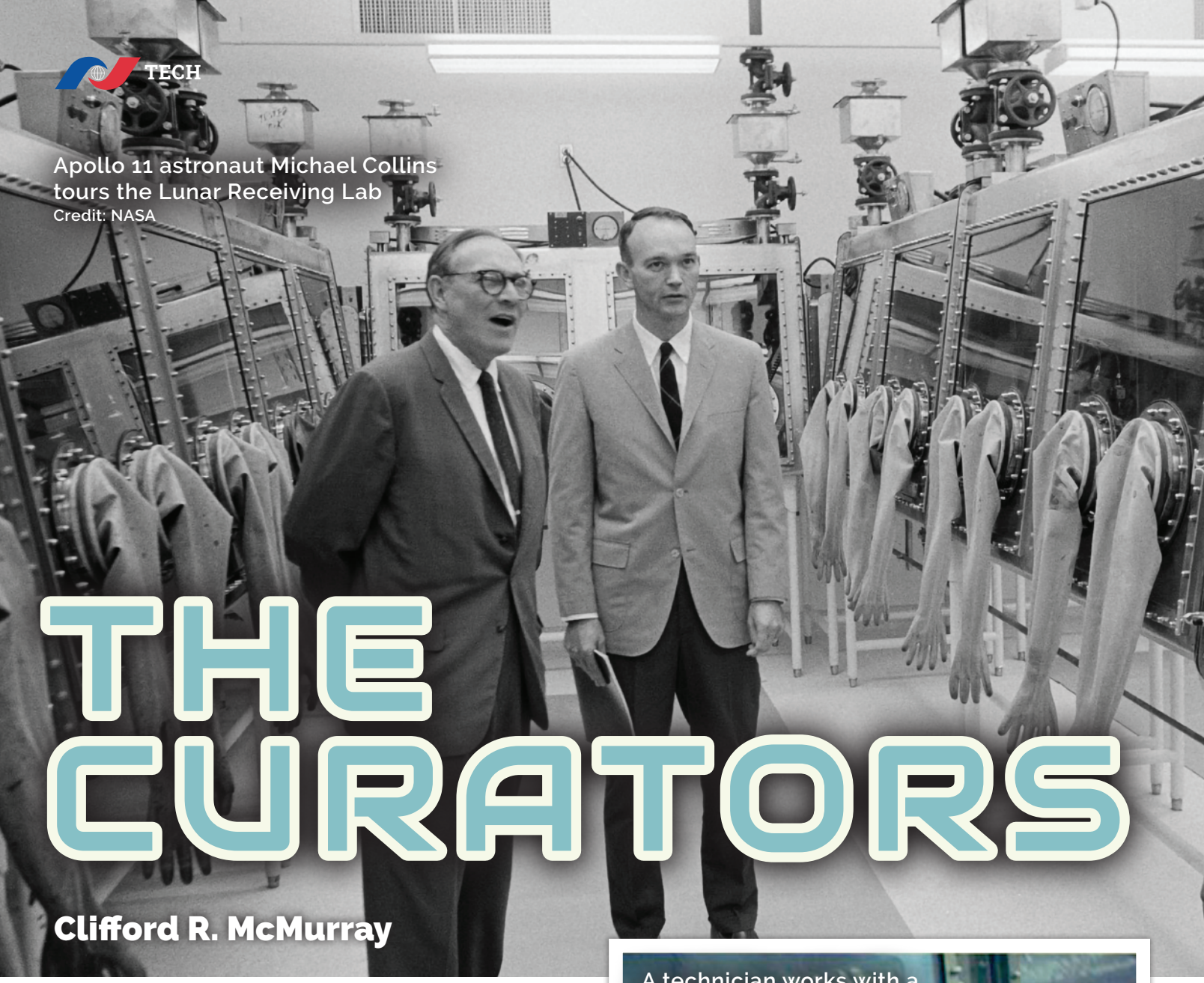
The two-day hearing did little more for Cobb and Hart than reinforce the status quo. By its conclusion, two things had been made clear. The first was that NASA's astronaut requirements were sound. The second was that if they were to explore the idea of women astronauts, it would happen at a later date. The fight was over, and none of Lovelace's female test subjects would fly in space. Eleven months later, Soviet Cosmonaut Valentina Tereshkova became the first woman to do so.

AFTERBURN

This story has spent decades buried in the margins of space history. In some circles, the women's ambitions have been laughed off as delusional, their efforts as absurd; but perhaps a revised perspective is in order. Maybe it's time to see these women as part of an extraordinary generation, people who dared to conjure big dreams and then work to see them realized. These were pilots who spent their entire lives struggling against the notion that flying planes was only for men. They all carved out places for themselves in American aviation. Was it really so unrealistic to dream of something similar in spaceflight?

The women who threw themselves into astronaut testing were simply doing what women pilots had always done: ignoring the naysayers, climbing into whatever cockpit they could, and showing the world what they could do.

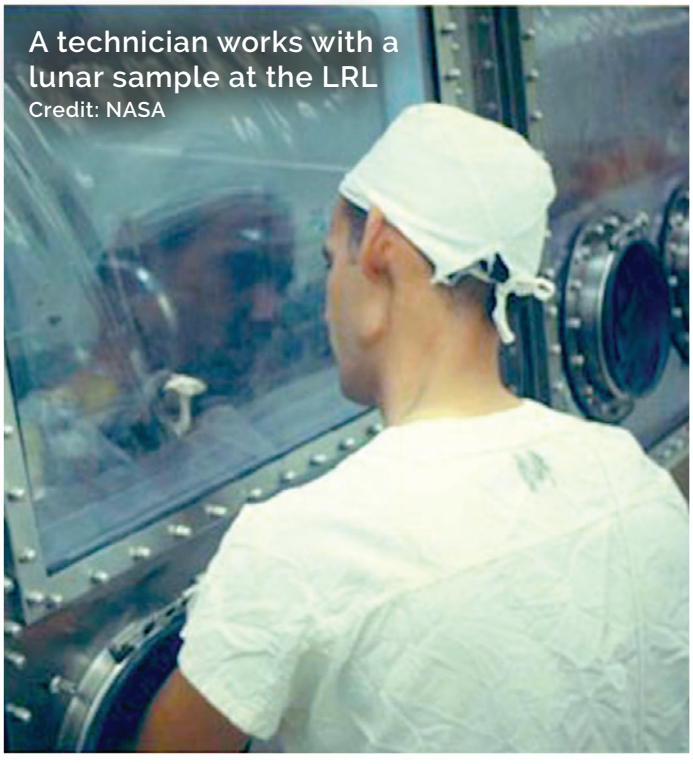
Margaret Weitekam refers to Lovelace's women astronaut testing as "an unexpected program" that "briefly took flight." It's an apt description for a program that flew on the wings of curiosity and hope, and then, all too soon, was grounded by shortsighted policy. In 1995, Eileen Collins became the first woman to pilot a spacecraft. Seven of Lovelace's astronaut test subjects attended the launch. They were thrilled that, after 35 long years, an American woman was finally achieving the most audacious of dreams: flying in space.



Apollo 11 astronaut Michael Collins tours the Lunar Receiving Lab
Credit: NASA

THE CURATORS

Clifford R. McMurray



A technician works with a lunar sample at the LRL
Credit: NASA

On the morning of July 28, 1969, geologist Ross Taylor was feeling the pressure. Just four days after Apollo 11 had splashed down in the Pacific, at 11:45 a.m., he was about to put the first sample of lunar regolith under his emission spectrograph. The work conditions were difficult, and he only had a tiny amount of Moon dust in a nitrogen-filled glove box. Nevertheless, working faster than usual for typical sample analyses, much less such a historic one, by 4 p.m. the visiting professor from the Australian National University delivered his preliminary results at an afternoon press conference. "When other people measured it later," says Judy Allton, they found that "he did a pretty good job."

Allton, who came to the Lunar Receiving Laboratory (LRL) at Houston's Johnson Space Center in 1974, missed the excitement of the first opening of the rock boxes from the Apollo missions, but she's been working at the laboratory and its successor, the Lunar Sample Laboratory Facility (LSLF) ever since. Today she's one of seven curators of the samples stored there from Apollo and other missions; her responsibility is the single milligram (a few grains of

salt worth) of solar wind particles returned by the Genesis mission, the first to return material from beyond the Moon. It's not much compared to the 842 pounds (382 kilograms) of rock and dirt brought back by the Apollo astronauts, but "you can do a lot with those tiny particles," she says. Referring to the Stardust mission that retuned a comparably small sample of dust from comet Wild 2, she explains that "grains of Wild 2 from Stardust aerogel [the material used to capture the sample] can be subdivided; 10 micron grains can be subdivided among 10 research groups." The ability to analyze such tiny samples shows how far planetary science has come since the Lunar Receiving Laboratory first opened for business.

When NASA first started thinking about what kind of facility they would need to handle the samples that would be coming back on the Apollo missions, they imagined it would occupy a much smaller space. A 1964 proposal by a small team headed by NASA facilities engineer James McLane Jr. called for just a single room of 110 square feet (10 square meters). This space would serve the sole purpose of opening the boxes of Moon rocks in a sterile, high-vacuum chamber and repackaging them for distribution to scientists in laboratories all over the country. After some discussion, that single room was expanded to about 2,400 square feet (223 square meters) so some initial analysis of the samples could be done before they were sent out of the laboratory. Then it grew to 7,800 square feet (725 square meters). In 1965, faced with concerns from the U.S. Public Health Service that the rocks might carry extraterrestrial microorganisms against which Earth life would have no defense, NASA expanded the laboratory again to provide a quarantine facility for the returning astronauts. When Neil Armstrong and his crew got back to the Johnson Space Center in Houston, they and their precious sample boxes stepped directly into a Lunar Receiving Laboratory that had grown to 84,000 square feet (7,800 square meters).

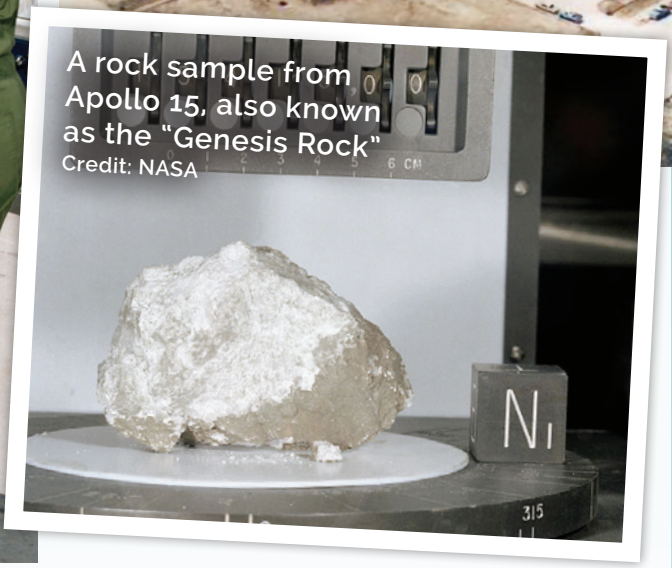
The astronauts thought the three-week quarantine was silly and unnecessary (though in the end Armstrong, Aldrin, and Collins admitted that they valued the "down time" to decompress prior to the public relations whirlwind that would follow). What kind of life could survive in vacuum, hard radiation, and temperature swings of many hundreds of degrees that alternately froze and baked the lunar surface, they wondered? When Deke Slayton, chief of flight crew operations, heard about it, McLane said "he just about flew out the window." But NASA had meetings with the Surgeon General of the United States, and his attitude was: "How much is the Apollo program going to cost? Twenty billion dollars or so? I don't think it is outlandish to set aside one percent of that to guard against great catastrophe on Earth." When completed, the Lunar Receiving Laboratory cost nine million dollars. The cautious voices that had prevailed with the quarantine may have felt vindicated when Apollo 12 brought back a piece of the Surveyor 3 probe, and it was announced that a small colony of *Streptococcus Mitis* bacteria had stowed away and survived on the Moon for three years before being brought home. It later turned out that wasn't true—the scientists examining the Surveyor 3 camera had themselves contaminated it. The Apollo 14 crew was the last to endure quarantine.

It didn't take long to realize that the procedures for handling the lunar samples could be improved. The original vacuum-sealed glove box for opening the boxes of Moon rocks, built at the Oak Ridge National Laboratory, was very high maintenance and working with its stiff gloves was as difficult as working in a spacesuit. Most sample handling was done in negative pressure nitrogen-filled glove boxes. After Apollo 12, when it was clear the samples were sterile, the curators changed to positive pressure glove boxes that were much easier to work with. By the mid-1970s, NASA wanted to build a brand new laboratory. The Lunar Sample Laboratory Facility was dedicated on the tenth anniversary of Neil Armstrong and Buzz Aldrin's Moonwalk, July 20, 1979. The two-story, 14,000-square-foot (1,300-square-meter) building cost two and a half million dollars. Although smaller and less expensive than the Lunar Receiving Laboratory, it's a much more capable facility built with input from the scientists who use it. "Most of them were isotope geologists and they were really picky about the materials" that went into its construction to keep the samples pristine, says Allton. The pride in her voice is evident when she observes, "I think it looks just about as new and spiffy as it did in 1979, because we take real good care of it."

The Apollo 11 sample boxes were loaded with 48.5 pounds (22 kilograms) of Moon rocks and dirt, but that was just the appetizer for lunar geologists. In the three years that followed, five Apollo landing missions would return another 793.5 pounds (360 kilograms) of materials. The Apollo explorers brought back 2,200 samples in total, and the analysis of those

Lunar surface samples being unloaded into the LRL
Credit: NASA

Construction of the final version of the LRL
Credit: NASA



A rock sample from Apollo 15, also known as the "Genesis Rock"
Credit: NASA

samples has continued ever since. Today, an independent peer review panel evaluates new research proposals, and every year the Lunar Sample Laboratory Facility curators mail about 400 samples (most less than a gram) to scientists all over the world. Roughly four out of five requests for samples are approved, and those that don't are given feedback to improve their research proposals.

When the Soviet Union flew three robotic lunar sample return missions in the 1970s, NASA exchanged some of their Apollo samples for those from the Luna probes. It was a small exchange of just a few grams, but since the Soviets had only a little over 300 grams of material (about three-quarters of a pound), even though NASA gave up more than they received, the Russians traded a much higher proportion of what they'd retrieved to begin with. Those Apollo and Luna samples, along with solar wind samples from the Genesis solar wind probe and Japanese Hayabusa asteroid mission, are stored in the Lunar Sample Laboratory Facility itself, but there are other sample collections within an older building attached to the laboratory. There are samples of interstellar dust and comet dust returned by the Stardust mission, thousands of meteorites picked up in Antarctica (which originally fell to Earth from the Moon, Mars, and various asteroids; these represent a passive sample return), and a collection of cosmic dust filtered out of the Earth's upper atmosphere by NASA's WB-57 and ER-2 aircraft. In the next few years they'll be joined by samples from near-Earth asteroid Bennu, collected by NASA's OSIRIS-Rex mission, and JAXA's Hayabusa2 samples from asteroid Ryugu. At a minimum two ounces (60 grams), and possibly as much as 4.5 pounds (two kilograms), the haul from OSIRIS-REx may be the biggest sample return since the Apollo missions.

Over the half century since they were collected, the Moon rocks that have been examined have gotten a bit smaller. "The samples when they get handled suffer some attrition, and some experiments require total destruction to make the measurement," says Allton. All the cataloged samples have a detailed history of how and when they've been handled and tested, but about 80 percent of the samples have never been out of curatorial custody. They're kept in pristine condition in a separate vault, awaiting the time when the tools available to examine them are better than those available today, just as today's scientists have better tools available to them than those that were available in 1969, or even a decade ago. NASA administrator Jim Bridenstine announced last March that nine teams from within NASA and various universities have been selected to look at a few of the previously untouched samples from Apollo 15, 16, and 17.

Bridenstine said NASA feels comfortable releasing those samples now, since it expects a new generation of lunar explorers will be bringing more samples back to Earth in the next few years. When that occurs, Allton and her colleagues at the Lunar Sample Laboratory Facility will be waiting.

CREATING *A DAY IN SPACE*

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

On July 16, the National Space Society premiered its new streaming video production, *A Day in Space*. This exclusive event was open to the public and presented at no charge as an NSS public service in this time of COVID-19. It was also a nod to the cancelled ISDC® 2020 and utilized many of the speakers who were scheduled for that event.

A Day in Space ran for over seven-and-a-half hours and was seen around the globe. It was presented on the NSS Facebook page and multiple set-top services such as Roku, Apple TV, Amazon Fire, and many others courtesy of e360tv.com. Through an exclusive arrangement brokered by *Ad Astra*, the show was also carried on Space.com's website and their YouTube channel, which has over one million subscribers.

The NSS Facebook feed and Space.com's YouTube channel were interactive and much discussion was enjoined by the global audience. Total viewership across all channels topped 40,000 people, which makes this one of the most successful pieces of NSS outreach yet. Feedback has also been overwhelmingly positive.

A Day in Space is archived on Space.com's YouTube channel and the NSS YouTube channel for viewing at your convenience and continues to rack-up new viewers. Presentations include:

An exclusive interview with Board of Governors member and Apollo astronaut Buzz Aldrin by NSS president Geoffrey Notkin,

A panel of three Apollo astronauts—Apollo 13's Fred Haise, Apollo 15's Al Worden, and Apollo 7's Walt Cunningham—along with Flight Director Gerry Griffin, moderated by *Ad Astra* Editor-in-Chief Rod Pyle (recorded in 2019),

Astronomer Dr. Sara Seager speaking about finding exoplanets,

Dr. Alan Stern talking about the New Horizons mission to Pluto and Arrakoth,

NASA's Jet Propulsion Laboratory Chief Engineer and Rod Pyle talking about Mars exploration,

NSS Board of Governors Chairman Karlton Johnson addressing diversity and inclusion in the space trade,

NSS Director of Communications and Branding, Dr. Anthony Paustian, speaking on the elements of success,

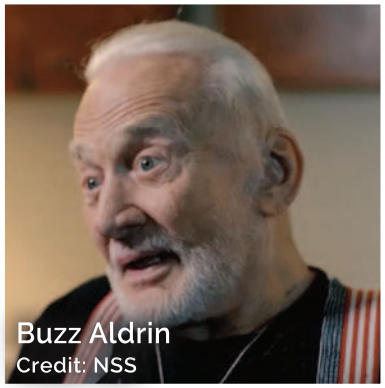
Analog astronaut and medical doctor Shawna Pandya speaking on space medicine,

NewSpace investor Steve Jurvetson talking about the future of financing NewSpace ventures.

The presentations were framed by an insightful and engaging conversation by Notkin and analog astronaut and planetary scientist Dr. Sian Proctor. Additional short presentations were given by a number of young NextGen speakers.

"As an executive producer of *A Day in Space* in addition to co-host, my mission was to demonstrate, not just talk about, our show's commitment to the National Space Society's goals," said Notkin. "Those goals include advocating for the peaceful exploration and settlement of space through international cooperation, the recognition and meaningful inclusion of women and people of color in the space industry, and support for students and up-and-coming professionals."

From left—Rod Pyle, Gerry Griffin, Al Worden, Fred Haise, and Walt Cunningham
Credit: Anthony Paustian


Buzz Aldrin
Credit: NSS

Paustian said, "*A Day in Space* helped the National Space Society showcase its mission and provide engaging, educational content for both members and non-members alike. This was a huge first step in our plan to increase public awareness of the many opportunities and insights that space has to offer. We look forward to providing an ongoing stream of similar content to engage and inspire new audiences for the NSS."

Aggie Kobrin, who is the executive producer of the annual International Space Development Conference®, added, "During a difficult time when we had to make some important decisions, we chose to do a professional online event with many options for viewing."

A Day in Space was months in the making and comprised of many moving parts. The production team included Notkin, Paustian, Pyle, Kobrin, and NSS Conferences Committee chair Dave Dressler. Program content was provided by Paustian courtesy of his conference, ciLive!, held annually in Des Moines, Iowa. Streaming was provided by e360tv.com's Aaron Heimes. Tariq Malik and Steve Spaleta provided support at Space.com, and to them we extend our deepest thanks. Avinash Shirode of the Nashik India NSS chapter provided publicity for the India region, from which we drew many viewers. Burt Dicht, the chair of the Membership Committee, provided much support. Downlink editor Fred Becker, Pyle, and Dressler provided much-needed support for the interactive discussions on the day of the presentation.

The NSS will continue to produce more programming like *A Day in Space*. If you missed it, it can be viewed on the NSS and Space.com YouTube channels as well as e360tv.com. Our deepest thanks to everyone who participated in making *A Day in Space* a success.

BROADENING SPACE HORIZONS: NATIVE AMERICAN GIRLS IN SPACE

Czarina Salido

It's exciting to take young girls on a passenger plane for the first time. Most of the students I work with for my nonprofit organization, *Taking Up Space*, have never left their home state before, and the experience of going to an airport and climbing into the sky is both scary and thrilling for them. Less than a week later, I was watching those same girls walk across a stage under a Saturn V rocket. Filled with a new confidence, they were awarded wings by an astronaut, having completed an intensive course of training in spaceflight simulators. At that moment, flying in a passenger jet seemed tame by comparison.

Taking Up Space works to broaden the horizons of its young participants and help them to become the person they want to be. America faces a serious educational deficit in retaining middle school girls' interest in STEM (Science, Technology, Engineering and Math) and related areas. For too long, women and people of color have been underrepresented in these kinds of careers and opportunities.

According to the Girl Scout Research Institute, "Girls start losing interest in math and science during middle school … Women account for about only 20 percent of the bachelor's degrees in engineering, computer science, and physics." Due to this trend, the U.S. faces an overall reduction in our future science, technology, and educational workforce, whereas globally the reverse has occurred. For women of color, the numbers are even lower, and NASA reports indicate the number of such engineers in their employ remains around 5.5 percent. NASA has a number of admirable initiatives to raise that number, but the agency also reports that many of the women who do make it in feel isolated, without effective mentorship to help them feel welcomed, and some do not stay long.

I've experienced something similar myself, and I remember feeling that I couldn't do the same things the boys could do when I was in elementary school. I thought I couldn't be as good at math and science. I didn't really know why, which made it even more unsettling. As a Hispanic female, I had to fight to overcome numerous negative assumptions and obstacles, but the challenges helped me develop a greater sense of purpose. My teachers always stressed the importance of learning science and mathematics, so I joined the Mathematics, Engineering, and Science Achievement (MESA) group in high school. Though it was a struggle, I graduated and went on to college to study physics. Compared to some of my peers, I was lucky to overcome those negative feelings and to have some great teachers who would become mentors.

Czarina Salido with young participants at the Yaqui reservation
Credit: Geoffrey Notkin

Knowing about these issues firsthand, I wanted to provide assistance to other young women. In my Arizona community, there were many successful science-themed groups for girls, but I found none that specifically encouraged young indigenous girls. Native American youth face unique hurdles in education. A number of reports have indicated that they are less likely than any other group to graduate from high school, placing these students at a serious disadvantage when it comes to career choices. That was the genesis of *Taking Up Space*.

We work with Native American students, primarily girls from the PascuaYaqui tribe from the Tucson, Arizona area. Many of these students soak up STEM subjects with excitement. We create activities for them that are collaborative, because they generally enjoy working with their friends. These are hands-on activities; projects that involve making and testing things that may benefit them more than textbook work. The students are encouraged to experiment and come up with their own creative solutions as inventors have done for centuries.

To increase their chances of success, it's hard to imagine a more inspirational place than Space Camp in Huntsville, Alabama. For four decades, young people have attended programs there and learned what it takes to be an astronaut. Some attendees have gone on to fly in space, and many more went on to have important careers in science and engineering. All were inspired to follow their dreams. However, it takes a lot of work beforehand to energize the community—from banks, to aerospace museums, to supportive space enthusiasts—to successfully secure tuition for the program.

Space Camp participants learn cutting-edge ways of exploring space alongside other students from around the world and receive mission training directly from a former space shuttle astronaut. In the course of a week, they work in teams to fly simulated missions to the International Space Station, design a Mars base, launch model rockets to learn about propulsion, and put on spacesuits before hanging from special harnesses to simulate spacewalks. They gain an understanding of human spaceflight and become better team players. The students had already studied space from the unique viewpoint of their tribe, which believes that their ancestors became stars in the night sky. This gave them a connection to the universe they were exploring, and each brings a unique perspective to share with other participants.

Once they're back home, many students in underrepresented communities are marginalized and don't get the networking opportunities that other students receive. Therefore, providing them with mentors gives the girls opportunities to talk about and plan for their future, and they also get to meet people who they can imagine themselves becoming in 10 or 20 years. Many participants have spent time in the University of Arizona's world-class space science laboratories and workshops, and the people they aspire to be like are now only a text message away.

Graduation at Space Camp
Credit: Taking Up Space

Participants inside a cockpit at Atlanta airport
Credit: Taking Up Space

Recently, three students from the Pascua Yaqui tribe presented a report about their experiences at their tribal council. It was moving to see the emotional reception that these children received. The council members expressed how proud they were, and how inspiring these youths were to both adults and children. They praised their courage and were supportive of their interests: "This gives me great hope to see the first Yaqui on the Moon, so hopefully you'll get there, or Mars, or anywhere else you want to go," one said. They were lauded as role models and ambassadors by many in their tribe.

Growing up in Tucson, with its dark skies, internationally known space-themed university courses, and world-class observatories, has instilled in me a lifelong sense of wonder and curiosity. It's one of the best places in the world to appreciate the immensity of the universe and to also learn about it from experts. I hope these students will continue to feel that sense of wonder.

It's impossible to say whether these girls will become astronauts or rocket engineers, but I know that providing these opportunities is like throwing a stone in a pond: the ripples touch everywhere. These students now understand the importance of setting goals, and even if those goals change, they won't be afraid of continuing to make progress. They have a new confidence and self-esteem that will benefit them throughout the course of their lives, and their horizons have been broadened.

If we hope to create a society that believes in the benefits of space exploration, and science in general, we have to engage young people. Students who learn to appreciate STEM subjects may not pursue STEM careers, but they will know why they are important. Just as the National Space Society is a positive advocate for a spacefaring future, involving young people from many cultures in space sciences through personal experience will help create the kind of world—and worlds beyond—of which we dream.

STUDENTS SHINE A LIGHT ON CREATIVITY IN THREE NSS COMPETITIONS

Lynne F. Zielinski

The National Space Society and its educational arm SpacEdge Education host space settlement and development educational programs, competitions, and contests involving teachers and students from middle school up to the university level from around the world. Three student competitions and contests chose winners this spring, after nearly 15,000 students and 2,000 teachers from 23 countries shared innovative and creative concepts. The Health for Space competition offered university students its "Plan a Diet to Support Long-Duration Space Flight" contest, and university student teams throughout Mexico competed in the International University Robotics for Space Settlement Competition.

NATIONAL SPACE SOCIETY SPACE SETTLEMENT CONTEST

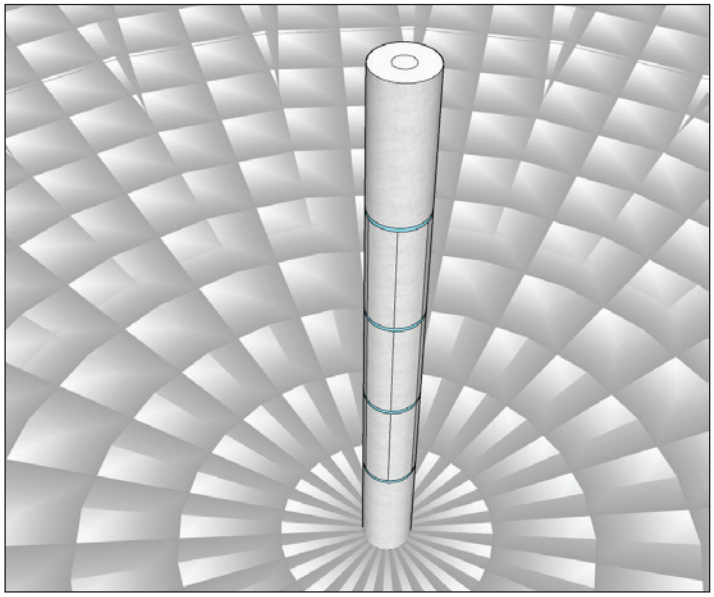
For more than 25 years, the NSS Space Settlement Contest, founded and run by National Space Society Director Al Globus, was administered by the NASA Ames Research Center. Winners were showcased by the NSS at its annual International Space Development Conference®. In 2019, the NSS took over administration at NASA's invitation and transformed the entry process from paper to an online submission system. The goal of this contest is for students to envision space settlement designs anywhere in the solar system not located on a planet or moon.

Teachers are encouraged to use this successful competition as a part of their lesson plans. While designing a space settlement, students engage the study of physics, mathematics, space science, environmental science, and many other disciplines. Students outside of science disciplines may participate as well. Contest submissions may include designs, essays, stories, models, experimentation, and artwork.

This year, 14,359 students from 22 countries submitted more than 2,646 designs from which the grand prize was selected. The grand prize winner for the 2020 NSS Space Settlement Contest was Sean Kinney for his project *Stern Habitat: Colonization of the Kuiper Belt with Current Technology*. Sean is an 11th grade student from El Toro High School in Lake Forest, California, and his physics teacher is Trevor Strickland.

NSS Space Settlement Contest Grand Prize winner Sean Kinney, an 11th grade student from El Toro High School in Lake Forest, California
Credit: Sean Kinney

Sean's novel settlement orbits an object named Arrokoth located in the Kuiper Belt, a vast belt of primordial solar system detritus beyond the orbit of Neptune. The settlement's design focuses on the utilization of technology that is currently available, making his design achievable in the near future. The habitat's design is very detailed and based on research to optimize size, auxiliary power, structural support, and food production. Areas devoted to industry and mining production emphasize methods of processing materials from Arrokoth. Upon presentation of his project, Sean will also receive the Herman Rubin Memorial Scholarship of 5,000 dollars. The project paper can be downloaded from bit.ly/2OKoGcJ.



A close-in view of the central part of Sean Kinney's Stem Habitat space settlement where people would live
Credit: Sean Kinney

HEALTH FOR SPACE COMPETITION

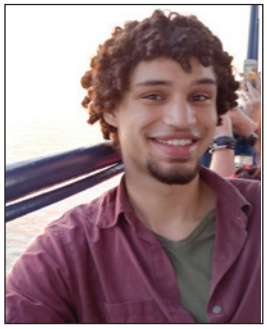
In cooperation with Mars Academy USA (MAU), the NSS has awarded two prizes in its first annual Health for Space Competition. Founded and run by former NSS Director and current chair of the NSS Space Health and Medicine Committee Bill Gardiner, this year's competition addressed the types of food and diet necessary for exploration-class space missions with a challenge to plan a diet for long-duration spaceflight. Topics for the university-level competitions change on a yearly basis.

The first-place winner was Alix Jones of Ireland, a diet and nutrition university student at King's College in London,

England. The second-place prize was awarded to Stellie Ford, an engineering graduate of Cornell and Drexel University in Bioengineering and Tissue Engineering, respectively, living in Philadelphia, Pennsylvania.

NSS "Plan a Diet for Long-Duration Space Flight" competition first place winner Alix Jones
Credit:Alix Jones

Alix's entry offered a detailed rationale for all components of a diet with supplements and macronutrients. She assumed that preserved food would be used, and her meal plan for a model week resembles the current International Space Station food plan. Alix will receive a 3,500 dollar scholarship prize that will be applied to the one-week mission at Mars Academy USA's low-fidelity analog facility.



NSS "Plan a Diet of Long-Duration Space Flight" competition second place winner Stellie Ford
Credit: Stellie Ford

Stellie's entry offered some innovations including intermittent fasting and the possibility of hydroponically growing some foodstuffs along the way. Stellie will receive a 1,000 dollar scholarship prize and participate in the same MAU analog mission with Alix.

Both winners' plans stated that nutritionists planning for long-duration space flight should focus on a relatively high carbohydrate diet until there have been more studies about how a ketogenic diet containing high fat and protein work in practice.

In preparation for the analog mission, the winners will adapt their food and nutrition plans to be used by the crew participating in the Mars Academy mission in 2021. These seven-day simulated missions consist of two days pre-mission, four days in-mission, and one day post-mission. There are three levels of missions: low-fidelity (entry level), mid-fidelity, and high-fidelity. The awarded mission is a low-fidelity mission to be conducted in California, as subsequent mid- or high-fidelity missions require completion of the low-fidelity mission.

INTERNATIONAL UNIVERSITY ROBOTICS FOR SPACE SETTLEMENT COMPETITION

Settlers on the Moon or Mars will likely use robots to gather surface materials and work outside of settlements telerobotically. Inspired by presentations given by NSS Executive Vice President Alfred Anzaldúa at the National Autonomous University of Mexico in Ensenada, Mexico, university students suggested a telerobotic competition and the International University Robotics for Space Settlement Competition was founded.

Astronomy professor Aida de Wofford from that same university took up the challenge of organizing 46 professors from 32 universities and technology institutions in Mexico. The competition promotes the NSS strategic objective of encouraging STEM education and involving teams of students that support diversity and the involvement of women—29 percent of the 311 students participating were female, and there are hopes of expanding the competition to include other countries in the future.

In this first annual event, the competition was divided into three stages. Stage one consisted of a workshop held in June, 2019 that focused on development and was open to all students. The workshop was held in Monterrey, Mexico and attended by more than 200 students from 32 institutions. There was at least one representative from each of the 57 teams of five or more students each. Twelve Mexican states and one federal entity were represented with over 30 percent of them including female students.

Stage two occurred in October, 2019, in Puebla, Mexico, where the 57 teams were pared down to 20 through a design component review. Finally, in March, 2020, 14 of the remaining teams participated in a telerobotic prototype 'in-the-field' demonstration to select the winning team. To win the third stage of the competition, the rovers had 15 minutes to collect as many rocks as possible. The winning rover had to traverse a diverse terrain where some of the rocks were partially buried and others sat on top of sand or dirt with pebbles. The rover that collected the most mass won the competition.

The 2020 winning team was RAMS from the Autonomous University of Baja California in Mexicali, Mexico. They will receive a 5,000 dollar scholarship and demonstrate their robot at an upcoming NSS event. Team members included students Juan Jaime Siqueiros, Ashley Pamela Fernández Rojas, Ambar Camila Ayón Zamora, Anada Fernanda Espinoza González, José Andrés Morales Palomares, Ramón Alberto Gallegos Flores, and Luis Eduardo Corrales Mendoza. The mentoring professor was Jose Manuel Ramirez Zárate.

Members of RAMS, the grand prize-winning team of the International University Robotics for Space Settlement competition, celebrate their victory
Credit: NSS

This global collaboration of students and educators demonstrated their passion, depth of knowledge, and innovation through their exemplary projects. The NSS would like to thank all the students, teachers, parents, and mentors for their enthusiasm and dedication to making the human settlement of space a reality. We hope to embrace the youth and innovation of a new group of students at ISDC 2021 in Los Angeles, California, and more student and teacher opportunities can be found on the Society's website.

THE NSS GOES VIRTUAL
ON A SCREEN NEAR YOU!

Melissa Silva, with Larry Ahearn, Clair McMurray, and Burt Dicht

When asked about the primary reason they became involved with the National Space Society, members overwhelmingly cite wanting to learn more about space exploration, development, and settlement. Knowing this and having access to some of the industry's brightest and most accomplished minds, the membership committee has decided it's time to give members a way to tap into this resource through the new NSS Town Hall.

The first town hall focused on internal society topics such as membership benefits and the policy committee's recent work. The reactions from the audience were quite positive and, spurred by the COVID-19 pandemic and the need for social distancing, it was decided that NSS Town Halls would become a permanent fixture.

The NSS has been holding regular virtual events since April, and we are now offering two types of events: the NSS Town Hall and the Space Forums. The town halls are designed to introduce members to society leadership, educate members on their benefits, and hear directly from volunteer leaders about their exciting projects. Past topics include the NSS's new membership portal (InsideNSS), the SpacEdge Academy, the Space Ambassadors Program, the Hawai'i Space Exploration Analog Simulation, *A Day in Space*, and an exclusive, insider's view of *Ad Astra* magazine. The Space Forums feature industry experts eager to share the latest information regarding the space program and space settlement.

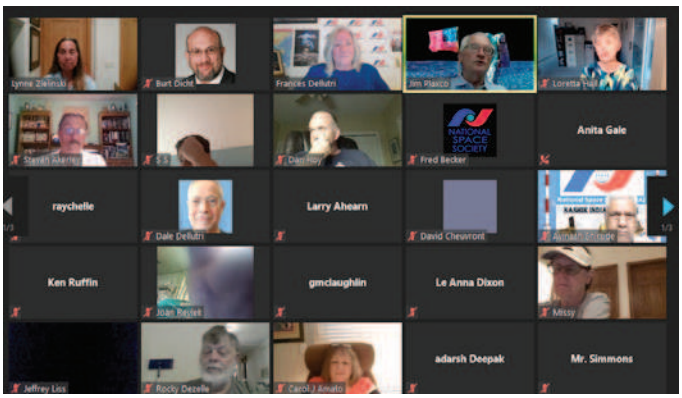
The National Space Society has been actively looking to make these events available to more people, and more than 1,000 members have attended. We are developing a schedule of future events, to be posted online, that will allow members to plan ahead. We are also working to make the presentation recordings available on demand. We hope you enjoy these presentations, so be sure to watch and feel free to contact Burt Dicht at burt.dicht@nss.org with any questions or feedback.

On Thursday, July 9, 2020, the Chicago Society for Space Studies, the Huntsville, Alabama L5 Society, and the National Space Society held a live meeting for a special event called *Planet Earth as Art: The View from Space*. Delivered by CSSS President and NSS Space Ambassador Jim Plaxco, the event makes the case that Earth is a work of visual art by using imaging data from the Landsat 8 satellite that was processed by Plaxco. The main presentation examined a variety of the planet's surface features selected for their aesthetic appeal and artistic value.

The NSS North Houston Space Society held its most recent meeting on July 11, where chapter member Greg Stanley, who holds a Ph.D. in Chemical Engineering, reported on recent news in the spaceflight industry. Yumna Majeed, an undergraduate student of the Allama Iqbal Medical College who is studying Medical Lab Technology, gave an illuminating presentation in which she expressed her dream of becoming an astronaut.

"As a school kid, I was told space has no scope in Pakistan. So, I decided to create it," said Majeed in an interview appearing in the MIT Technology Review. Believing that children should have answers relative to their "space imaginations" outside the classroom, she founded a space education social enterprise, called *Exploration*, in affiliation with a number of international space organizations. Thanks to Majeed's efforts, a science outreach session soon had young cancer patients creating artwork that was used to decorate a spacesuit.

The many chapters of the NSS, which thrive on face-to-face physical meetings within their regions, have been as challenged by the COVID-19 pandemic as the rest of us. Fortunately, due to the efforts of a number of energetic volunteers, virtual chapter activities are on the rise. Hats off to NSS chapters, which make the organization what it is today.



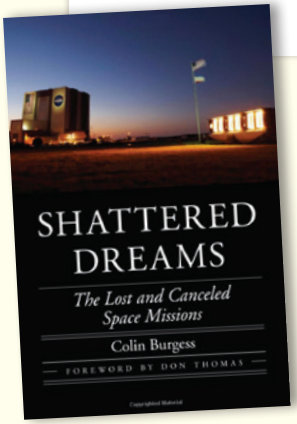
NSS virtual events are held via Zoom and are free to all members Credit: Burt Dicht

A screenshot of Jim Plaxco's orbital imagery of Earth
Credit: Jim Plaxco

SHATTERED DREAMS

AUTHOR: Colin Burgess **FORMAT:** Hardcover/Kindle **PAGES:** 288
PUBLISHER: University of Nebraska Press
ISBN: 978-1496206756 **DATE:** May 2019 **RETAIL PRICE:** $32.95/$16.99

>> Reviewed by Emily Carney <<



"What-ifs" have fascinated onlookers and enthusiasts alike since the beginning of human spaceflight. Even today, a popular topic of discussion among spaceflight fans continues to be alternate space histories; for example, what if Michael Collins had flown on Apollo 8 rather than Apollo 11? What if Vance Brand and Don Lind had flown a Skylab rescue mission, or Brand had flown on Apollo 15 instead of Al Worden? Apple TV+ recently released an entire series based on Apollo-era "what-ifs," *For All Mankind*, which was reviewed in a previous issue of *Ad Astra*.

While none of the aforementioned situations occurred, fate has changed the fortunes of many an astronaut or cosmonaut. The 2019 book *Shattered Dreams: The Lost and Canceled Space Missions* by prolific space historian Colin Burgess discusses some of the "what-ifs" that have occupied the minds of space enthusiasts throughout the last 60 years. *Shattered Dreams* runs the gamut from Vostok, Apollo, and Soyuz to the space shuttle, and showcases a wealth of diverse personalities who almost touched the stars but didn't quite make it due to bad timing, unpreventable personal circumstances, or a desire to move on to other ambitions.

The book opens with a discussion of the fates of the astronauts who were slated for Apollo missions, but were either replaced (such as Joe Engle, slated to fly on Apollo 17 but replaced by scientist Dr. Harrison Schmitt), or saw their missions scuttled by program cuts (Paul Weitz and Jack Lousma, who both eventually flew on Skylab missions in 1973). The Apollo-era theme continues for a few chapters, with the stories of Dr. Duane Graveline (a scientist-astronaut whose very brief career was scuttled by his chaotic personal life), John Bull (who developed a rare pulmonary disease during his short astronaut career), and Dr. Philip K. Chapman (NASA's first Australian-born scientist-astronaut).

The Chapman chapter is particularly wonderful and highlights what is best about Burgess' work in general. We get to know a person who has rarely been showcased in spaceflight history, and Chapman is fun to discover. He's direct and blunt-spoken, and one can almost hear his sometimes-curt words in an Australian twang. In addition, Chapman's testimonials of a late 1960s and early 1970s NASA—less focused on actual science and more on the macho test pilot, "boot prints on the Moon" mentality—contributes a lot to understanding the era, and why many astronauts in his group (including Dr. Brian O'Leary, who would write about his own time at NASA, 1970's *The Making of an Ex-Astronaut*) ended up leaving the corps.

We also discover the story of oceanographer Robert E. Stevenson and relive NASA's serious push to put an oceanographer on a shuttle mission during the early 1980s. His spaceflight dreams ended on January 28, 1986 by the *Challenger* disaster and the subsequent embargo of non-NASA space travelers on future missions. While Stevenson ultimately did not fly on the shuttle, he did complete his book *Oceanography from the Space Shuttle*, which is still considered a breakthrough publication in the field. We also learn about Frank Ellis, whose status as an amputee following a grisly, nearly fatal air crash did not end his ambitions to fly for the Navy and in space. We meet Marina Popovich, who, while married to cosmonaut Pavel Popovich, possessed space travel ambitions of her own and was a record-setting aviation pioneer in her own right, transcending the image of the dutiful, quiet wife.

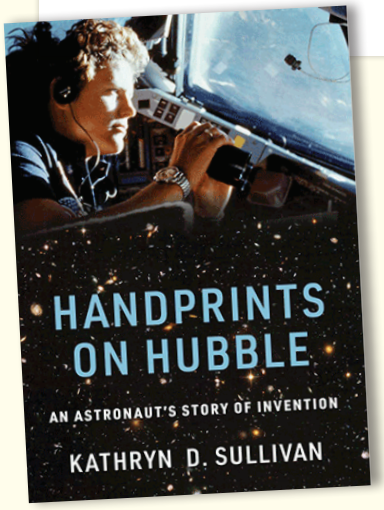
The stories are not limited to these astronaut and cosmonaut hopefuls, and longtime spaceflight followers will likely be surprised and excited to read about a wealth of personalities, many of whom were pioneers in their own right prior to having any spaceflight ambitions (but who ended up being mentioned as a footnote in many other spaceflight books or gained no mention at all).

What's notable about many of those profiled is that their careers didn't end with the cessation of the "space" parts of their lives. Marina Popovich, for example, continued her career as one of the Soviet Union's pioneering women pilots, and Stevenson, as mentioned previously, continued to publish and focus on space-based oceanography. The eminently quotable, incisive Philip Chapman may have expressed his situation best when he summarized the thoughts and feelings of many of those Burgess has profiled: "I have enjoyed an adventurous, rewarding life. I am of course sorry I didn't get into space, but that experience would have been just one more trinket on my string of memories." Life goes on, and Burgess captures what happened when it did quite brilliantly in *Shattered Dreams*.

HANDPRINTS ON HUBBLE

AUTHOR: Kathryn D. Sullivan **FORMAT:** Hardcover, Softcover, Ebook, Audiobook
PAGES: 304 **PUBLISHER:** The MIT Press
ISBN: 9870262043182 **DATE:** 2019 **RETAIL PRICE:** $26.95/$17.95/$23.98

>> Reviewed by Peter Spasov <<



Handprints on Hubble is part of the Smithsonian's Lemelson Center series on innovation and invention.

At first glance, the concept of maintainability hardly seems glamorous, but think of disassembling an automobile engine merely to replace an inexpensive part. Former astronaut Kathryn Sullivan, the first American woman to walk in space, highlights how designing for maintenance enabled a space telescope to revolutionize our understanding of the universe.

Overall, the book contains glamour, space thrills, and the high-stakes drama of corporate prestige. The author takes the reader into her world, where we learn the language used by astronauts, such as "stuck in transit," meaning to drone on indefinitely. The reader experiences how the Hubble Space Telescope and Sullivan's astronaut career developed in near parallel.

In the opening chapter, Sullivan describes growing up during the early space program and how she began her career as an oceanographer. The next chapter describes NASA's first group of astronaut recruits following the Apollo program, who colorfully coined themselves as Thirty-Five New Guys (or TFNG). She conveys the feeling of awe the candidates had for veteran astronauts. Some of the TFNG perform several firsts, such as the first space flight to successfully test a rocket pack, the Manned Maneuvering Unit or MMU. The chapter ends with a space shuttle mission to retrieve two satellites.

The history of the school-bus sized Hubble begins with Leonard Spitzer's vision of a telescope in space, The Hubble Space Telescope. It was the first spacecraft designed to be maintainable while in orbit. Sullivan portrays spacecraft maintenance as much like fixing an automobile while wearing an inflatable sumo wrestler suit and boxing gloves.

She and fellow astronaut Bruce McCandless tested Hubble's maintainability features and trained extensively on the procedures. The space telescope features modular architecture enabling the replacement of components during its operational life. Various specialized tools and features include an EVA wrench, an articulating portable foot restraint, electrical connectors with wing tabs, and a radical redesign of the main power unit for accessibility, among others. Techniques developed include tethered tools and captive fasteners, so that they won't float away. For example, McTether pins and sockets enable astronauts to remove or fasten items while wearing stiff and bulky spacesuit gloves that sap grip strength and remove the sense of touch.

During an instance of culture clash, the Hubble team initially refused to address certain orbital conditions varying from specification requirements (such as sufficient daylight prior to orbital sunset), whereas the astronauts planned ahead for many contingencies. A devilishly wicked simulation exercise designed to inundate participants with multiple problems eventually convinced the designers to heed the astronauts' advice. Also discussed is the corporate competition between the Marshall and Goddard Space Flight Centers, resulting in Marshall taking the lead for development and construction and Goddard running operations afterward.

Finally, during the author's second spaceflight, the space shuttle transported Hubble to orbit, and she and McCandless performed an EVA to maneuver the telescope while Steve Hawley operated the robotic arm. The mission had a few tense surprises, which the astronauts overcame to complete the deployment successfully.

Chapter nine illustrates an instance of scapegoating when early images revealed the lens was slightly out of focus. The media, politicians, and the public pounced upon the blunder. However, the lens shape was uniformly wrong, meaning it was correctable. It was ultimately fixed during a subsequent shuttle flight.

The author gives credit to many people who worked behind the scenes in order the make Hubble a success. For example, Sullivan had to pull some political strings to ensure Ron Sheffield, the head of Hubble's maintenance, repair, and refurbishment group, was also invited to the black-tie gala when the National Aeronautic Association awarded the prestigious Collier trophy to the Hubble Space Telescope Recovery Team. She gives credit to NASA's Goddard Space Flight Center for pioneering satellite servicing but criticizes them for reinventing the tools she and McCandless had helped develop.

Sullivan's writing style resembles an acquaintance taking the reader along for an adventure. This is a story of invention, and of designing and testing the tools, equipment, and procedures required for in-orbit satellite upgrades. There are also months of time spent to simulate tthe required spacewalks in a neutral buoyancy tank. The book's title refers to the handprints astronauts left on Hubble's outer skin while working on it. It includes a list of abbreviations, a comprehensive index, and 44 color photographs. Those who relish space history and admire gumption will enjoy *Handprints on Hubble*.

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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.

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