

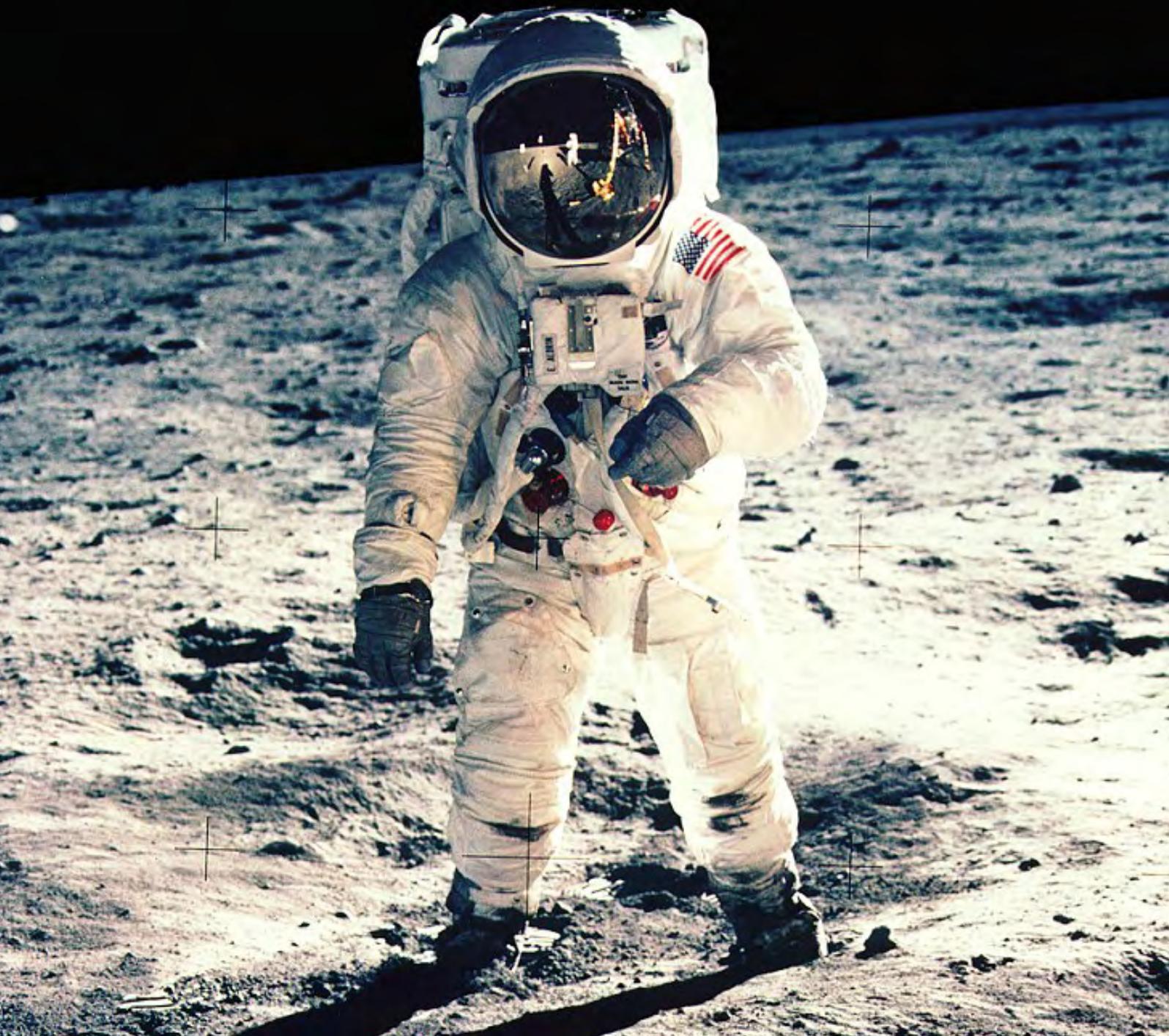
SPACE NEWS

BUSINESS | POLITICS | PERSPECTIVE

JULY 16, 2019

SN SPECIAL DIGITAL EDITION

Apollo 11 at 50



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SPACENEWS
VOLUME 30 | SPECIAL DIGITAL EDITION



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SPACENEWS (ISSN 2328-9376) is published bi-weekly in March, May, July, September, October, December and monthly in January, February, April, June, August and November by SpaceNews Inc., 1414 Prince Street, Suite 204, Alexandria, Va. 22314-2853, USA. SpaceNews is not a publication of NASA. **ANNUAL SUBSCRIPTION RATES:** \$219 U.S. Domestic mail; \$239 Canada; \$289 International mail. Periodicals postage paid at Alexandria, Va., and at other mailing offices. Postmaster: Send all UAA to CFS. (See DMM 7074.12.5); **NON-POSTAL AND MILITARY FACILITIES:** send address corrections to SpaceNews, P.O. Box 16, Congers, NY 10920-0016. SpaceNews is registered with the British Postal System and Canada Post International Publications Mail (Canada Distribution) Sales Agreement No. 546046. To order Space News, to change an address or for subscription information, call our toll free number (in the U.S.) 866-429-2199, or write to SpaceNews, Customer Service, P.O. Box 16, Congers, NY 10920-0016 or email spaceneews@cambeywest.com. For changes of address, attach an address label from a recent issue. **TELEPHONE NUMBERS:** Main: 571-421-2300; Circulation: 866-429-2199, fax 845-267-3478; Advertising: 571-356-0234. **PHOTOCOPY PERMISSION:** For permission to reuse material from SpaceNews Inc., ISSN 1046-6940, please access www.copyright.com or contact the Copyright Clearance Center, Inc. (CCC), 222 Rosewood Drive, Danvers, MA 01923, 978-750-8400. CCC is a not-for-profit organization that provides licenses and registration for a variety of uses. For bulk reprint requests of more than 500, send to SpaceNews Attn: Reprint Department.

Commentary | Arthur C. Clarke

The next space age

Twenty-five years after Apollo 11, Arthur C. Clarke outlined for *SpaceNews* an exploration vision marked by reusable launch vehicles and space elevators. The piece that follows first appeared in our July 18-24, 1994 issue.

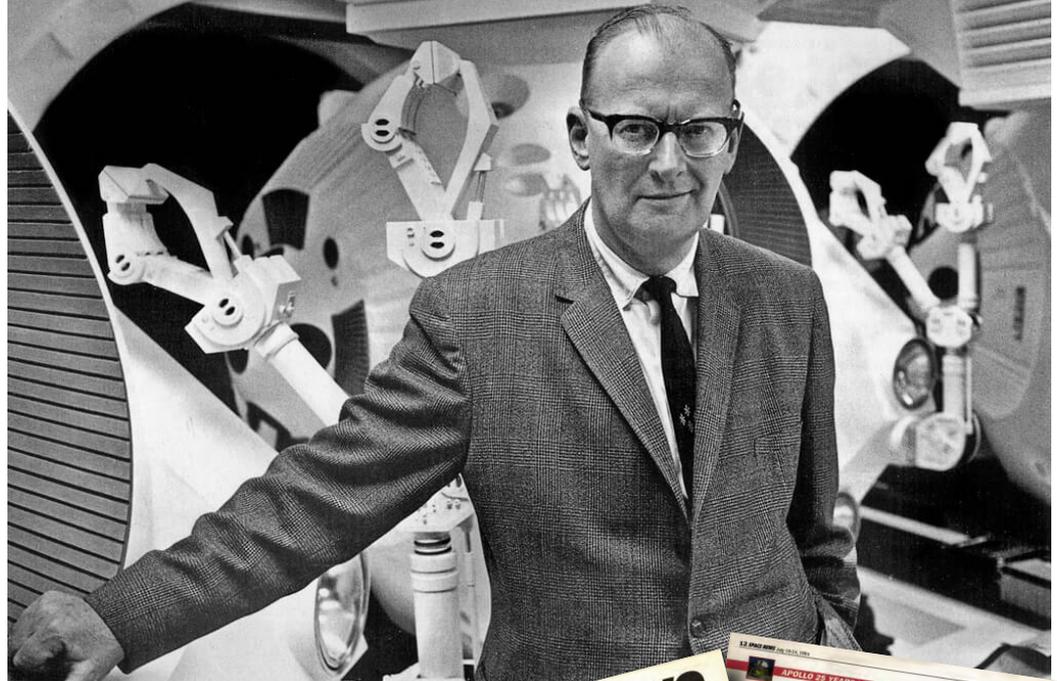
Some years ago, a well-known astronomer (no, it was not Carl) told me how he would get the United States moving again in space. "Turn all the existing programs over to Goddard and JPL," he said, "then surround NASA Headquarters with a regiment of Cossacks, and shoot anyone who tried to escape."

Such a scenario would require a somewhat greater degree of U.S.-Russian cooperation than has so far been contemplated, and does seem a trifle harsh, for many of NASA's problems should really be blamed on Congress, not to mention the Department of Justice which, in a disgraceful act of folly for which it later apologized, decapitated NASA at a critical time.

This, I suppose, is another critical time, when a decision has to be made on a redesign of the space station — or to bite the bullet and send it to join the Superconducting Super Collider and, any moment now, the hot fusion programs. But perhaps I am too biased to make a judgment on this: everyone knows what I — and Stanley Kubrick — think a space station should really look like.

Meanwhile, there are some good second-hand bargains in orbit, and the United States should make the best use of them.

The same applies to the state-of-the-art hardware developed for the recent Clementine mission, which demonstrates how we can explore the solar



system cheaply and examine Pluto early in the next century. I hope that NASA can avoid the not-invented-here syndrome, and at the same time keep unemployed Star Warriors out of mischief — until they are really needed.

It is also obvious that all future space operations must depend on reliable and cost-effective delivery i.e., fully reusable ones. The airlines would be in an even worse mess than they are now, if they threw away millions of dollars' worth of hardware at every takeoff. I am fascinated by the recent Delta Clipper flights, though some of my engineering friends doubt that a vehicle built to take off and land vertically can lift >



Sir Arthur C. Clarke, shown above in a 1965 photograph, outlined a vision for space exploration in a July 1994 op-ed for *SpaceNews*.

“It is also obvious that all future space operations must depend on reliable and cost-effective delivery i.e., fully reusable ones.”

< > worthwhile payloads to orbit. They may be correct, but I recall Simon Newcomb’s defense after the Wrights had cast doubt on his celebrated proof that heavier-than-air flight was totally impossible: “Anyway, they could never carry a passenger, as well as the pilot.”

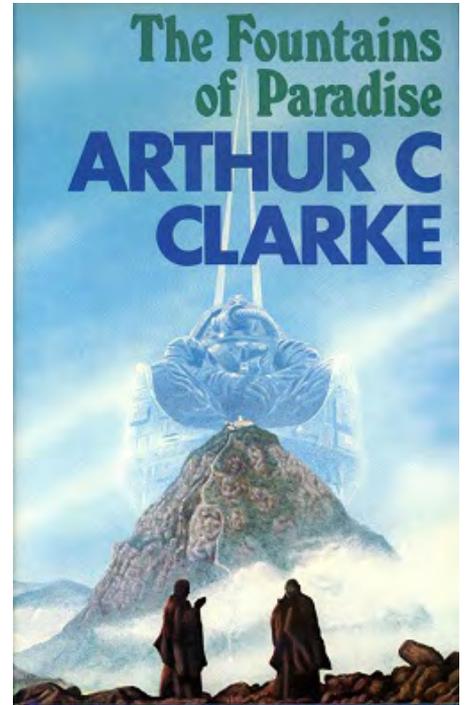
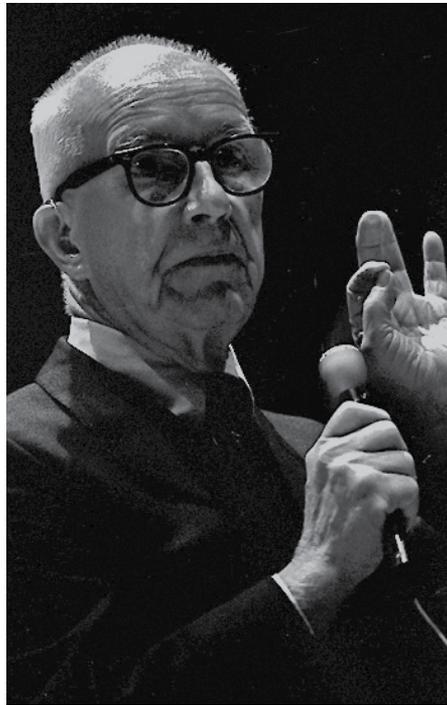
My guess is that the next generation of human-rated vehicles will be partial airbreathers, perhaps piggyback with a pure jet stage. We shall see, a decade from now. And then it will be time to go back to the moon and onto Mars.

But I must confess that I am no longer interested in rockets. They do not have much of a future, at least beyond 2100, a date which millions already born will live to see. There are already two hints of rockets’ replacement on the far horizon. The first is the space elevator, which must be taken seriously now that we have the material with which to build it. When Rice University’s Richard Smalley announced the discovery of the nanotube variety of buckminsterfullerene — the strongest material, he claimed, that can ever exist — he specifically mentioned the space elevator as one application.

The crew of the space shuttle also gave it a plug when they conducted the tether experiment in August 1992. During a press conference from orbit, Jeff Hoffman and his colleagues displayed a copy of “The Fountains of Paradise” and explained, “This is what it may lead to.”

And here is another eerie coincidence. Bucky Fuller, a long-time friend, drew a sketch of the space elevator, stretching up from Sri Lanka, for the sleeve-notes of my recording of “Fountains.” What a pity he never knew that the material named after him might one day make possible this most spectacular of engineering achievements.

Although the elevator could get us to geostationary orbit for essentially zero cost (about \$100 of electricity per passenger, a cost about 90 percent recoverable on



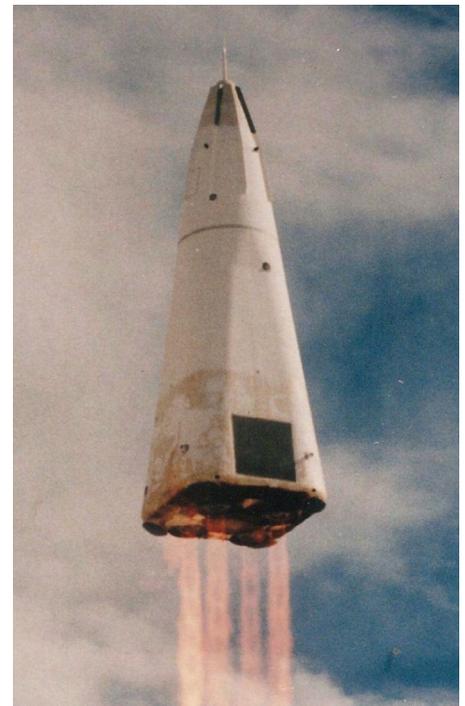
the way back) we would still need some method of propulsion thereafter. Rockets could certainly do the job — and cheaply, as propellant could also be lifted to orbit and most of it need no longer be wasted to fight the Earth’s gravitational field.

But there may be something better. Science-fiction writers have long dreamed of a mythical space drive that would allow us to go racing round the universe, or at least the solar system, without the rocket’s noise, danger and horrendous expense. Until now, this has been pure fantasy. However, recent theoretical studies — based on some ideas of [Soviet nuclear physicist and dissident] Andrei Sakharov’s — hint that some control may indeed be possible over gravity and inertia, hitherto a complete mystery.

This is a very long shot indeed, but the care and feeding of mathematical physicists costs peanuts. Only when they start digging tunnels do things get out of hand. If I was head of NASA — a nightmare from which I sometimes wake up screaming — I would get my best, brightest and youngest (no one over 25 need apply) to take a long, hard look at these equations.

Warp 5 anyone? Sorry — I just do not believe we will ever travel faster than light.

But then, I am a notorious conservative. Move over, Simon Newcomb. **SN**



Futurist Buckminster Fuller, top left, Clarke’s 1979 novel “The Fountains of Paradise” and the recent success of the DC-X reusable launch vehicle prototype were on Clarke’s mind when he outlined a space exploration vision on the eve of the 25th anniversary of the Apollo 11 moon landing.

NASA shakes up exploration team

Bridenstine says leadership changes linked to NASA's urgency to meet Trump administration's 2024 deadline for returning to the moon



NASA Administrator Jim Bridenstine said in a July 12 interview he needed to move quickly to change leadership of NASA's exploration programs to address cost and schedule issues in order to keep a 2024 human lunar landing on track.

NASA Administrator Jim Bridenstine said he reassigned the agency's human spaceflight head, Bill Gerstenmaier, because time was limited to address cost and schedule issues with the agency's key exploration programs and still meet a 2024 deadline for returning humans to the moon.

In an interview with reporters from *SpaceNews* and *The Washington Post* for C-SPAN's "Newsmakers" program July 12, Bridenstine also questioned whether commercial crew companies will be able to launch astronauts to the International Space Station by the end of this year.

The interview came two days after Bridenstine said he had reassigned Gerstenmaier, the associate administrator for human exploration and operations, and Bill Hill, deputy associate

JEFF FOUST

administrator for exploration systems development, to "special" positions. The announcement took many by surprise, particularly since Gerstenmaier was held in high regard throughout the space industry.

"We're moving to a new era in human spaceflight where the administration is interested in going fast, we're interested in doing things in a different way, and I believed it was important to have new leadership at the top of the Human Exploration and Operations Mission Directorate," he said. "I just thought it was important to make this decision, make this change at this time."

Bridenstine praised Gerstenmaier, who started at NASA in 1977 and had been associate administrator for human exploration and operations since NASA established that directorate in 2011. "He is a great American. He is a great patriot. He has served NASA for 42 years, and we love

him," he said. Bridenstine added that reassigning Gerstenmaier was "entirely my decision."

Bridenstine said he decided to reassign Gerstenmaier and Hill now, on the eve of celebrations of the 50th anniversary of Apollo 11, because of the schedule pressures created by the administration's goal of landing humans on the moon by 2024. "We don't have a lot of time to waste. If we're going to have new leadership, it needs to happen now," he said. "We need to move out quickly on all of our decisions."

Replacing Gerstenmaier on an interim basis is his deputy, former astronaut Ken Bowersox. Bridenstine said in a July 11 memo he plans to undertake a "nationwide search" to find someone to take the job on permanently, who would then hire two deputies, one for exploration systems like the Space Launch System and Orion and the other a new deputy associate administrator

responsible for efforts like Gateway and lunar landers.

"We're looking for three total individuals to create that top team" in the directorate, he said. "We will be looking for them to look at the programs and come up with their own baseline schedules and costs, and then ultimately have them execute to those baselines."

Bridenstine suggested that it will be up to that new leadership team in the mission directorate to make key decisions on reining in cost and schedule issues with those programs, in particular the core stage of the SLS. Delays in the development of that core staged Bridesntine to suggest in March that NASA could shorten or even skip a "green run" test of the core stage, where its four engines will be fired on a test stand at the Stennis Space Center for eight minutes. That proposal has faced criticism from some members of Congress as well as NASA's own Aerospace Safety Advisory Panel.

Bridenstine said that the agency has not decided about any changes to the green run. "I want to make sure we get those top people in place and then let them look at the program," he said. "Ultimately we'll let them make the determination of what tests needs to be done." He added, though that he expected that some form of the test would take place, "but how much of a green run do we need to do is the question."

"The key is this: we want to make sure, No. 1, our astronauts are safe, and No. 2, we are committed to cost and schedule," he said.

PAYING FOR ARTEMIS

The shakeup in leadership in NASA's exploration programs comes as the agency is trying to make the case to Congress for billions in additional funding >

Bill Gerstenmaier, NASA associate administrator for human exploration and operations, testifying at a House hearing July 10. Hours later, NASA Administrator Jim Bridenstine announced Gerstenmaier and another top exploration systems official were being reassigned.

< > for the Artemis program. In an interview with *CNN* in June, Bridenstine estimated that it would cost \$20–30 billion above the agency's previous budget projections to achieve the goal of landing humans on the moon by 2024.

"The challenge is political, for sure, but it's not partisan: it's not Republican or Democrat. It's largely parochial," he said. He cited the support from the administration in the form of a budget amendment, seeking an additional \$1.6 billion for the agency in fiscal year 2020 to work on lunar landers, SLS and other efforts related to Artemis.

He acknowledged the \$20–30 billion cost estimate, but suggested international and commercial partnerships could help reduce those costs. "What we're learning is that there are other people that want to contribute to this," he said. "They want to invest their own money. Why? Because they want customers that are not NASA. If they have customers that are not NASA, it drives down our costs."

"It's very realistic that it could come in well under the \$20 billion when I gave that original range," he said, which he said assumed NASA alone would pay for the cost of the program.

NASA has yet to secure that \$1.6 billion down payment for Artemis in 2020. A House appropriations bill passed in June did not include that funding, instead increasing spending for other agency programs, like science. Bridenstine said that the House's action was not surprising, since the budget amendment was released the same week as House appropriators marked up their bill.

The lack of House funding,



he argued, was not evidence of a lack of support for Artemis. "I've talked to people on both sides of the aisle that are, in fact, very supportive," he said. "The challenge is they just didn't have the time."

He said he hopes the Senate will act on the budget amendment, and that the additional funding for Artemis can be retained when the House and Senate reconcile their differing bills in a conference committee. "The process has only just begun. I'm confident that it can be achieved."

One area of concern, though, is that the 2020 fiscal year is likely to start on a continuing resolution (CR), as has been the case throughout recent history. Continuing resolutions, which fund agencies at levels of the previous fiscal year, restrict the ability to start new programs unless they're formally authorized through an "anomaly" to the CR.

"If that happens," Bridenstine said, "we need to look at how NASA can move forward in some kind of anomaly."

COMMERCIAL CREW DELAYS

Another key issue for NASA is its commercial crew program, where Boeing and SpaceX are developing vehicles designed

to carry NASA astronauts to and from the International Space Station, ending reliance on the Russian Soyuz spacecraft. Both companies, though, have suffered extensive delays, and Bridenstine hinted in the interview that the companies may not be ready to carry astronauts before the end of the year, as had been planned.

"I don't want to comment on whether or not we're going to get that flight complete this year," he said. "I honestly don't know at this point."

That comment was far less confident than what Bridenstine said two days earlier, speaking at the Future Space 2019 conference here, when he mentioned SpaceX's uncrewed test flight of its Crew Dragon spacecraft in March.

"That's a monumental achievement. It demonstrates a commitment for a very long period of time to returning American astronauts to space from American soil on American rockets. We're going to do that this year."

"We are moving rapidly to make these missions a reality," he said in the interview, noting it was still possible crewed test flights could launch this year. "I want to make sure that, before I go forward with what that launch

date will be that we know for sure that these vehicles are going to be safe."

SpaceX suffered the loss of that Crew Dragon spacecraft in April during preparations for an in-flight abort test. Both the company and the agency faced criticism for the lack of openness in the ongoing investigation into that incident, and Bridenstine vowed that the process will work differently in the future.

"That criticism largely comes from me as well," he said, noting there was "no communication" from SpaceX immediately after the accident. "That can't happen again."

Bridenstine said that a new process is now in place for communications in the event of another mishap. "Within a couple of hours, we're going to do a press conference and get as much information out to the public as soon as possible."

Updating schedules for commercial crew test flights, Bridenstine suggested, will be another task for the new leadership of the Human Exploration and Operations Mission Directorate as it deals with overall cost and schedule issues. "We are committed to commercial crew. We need to make it a go," he said. **SN**

Experts cite benefits, challenges of further space exploration



The United States has the advanced technology and capable workforce it needs for further space exploration. However, it lacks the focus and prioritization that assured the success of the Apollo program, Apollo flight director Gene Kranz told Senators July 9.

"We have an administration that is strongly supportive of space and willing to provide the resources," Kranz said July 9 at a Senate Commerce science and transportation subcommittee hearing. "We have an agency charted to do the mission, top level leadership in place and a very capable workforce. But each of the segments are philosophically divided on the goal." Without greater unity, the U.S. space exploration program "will be grounded," he added.

Kranz was one of the NASA veterans and industry leaders who discussed the Apollo program and the benefits and challenges of future missions at the hearing, "NASA Exploration Plans: Where We've Been and Where We're Going."

NASA plans to return astronauts to the lunar surface by 2024 and to establish a sustainable human presence on the moon

DEBRA WERNER

by 2028 through the Artemis program. To achieve those goals, NASA will need \$1.6 billion in additional funding in 2020 and an additional \$4 billion to \$6 billion per year above current funding levels after that, said Mary Lynne Dittmar, Coalition for Deep Space Exploration president and CEO.

"While funding increases are always a political challenge, it is worth noting that the benefits of ten times that amount in adjusted dollars invested in the Apollo program are evident to all, and form the foundation both for today's national effort and for the growing entrepreneurial sector," Dittmar said.

One of important benefit of Apollo was its impact on the U.S. workforce, Christine Darden, former NASA Langley Research Center strategic communications and education director, told the panel. Similarly, Artemis could prompt students to seek careers in science, technology, engineering and math, said Darden, a retired NASA mathematician, data analyst and aeronautical engineer.

"Sadly, after Apollo ended, there was a decline in the number of students getting degrees in STEM areas," Darden said. "A thriving, visible Artemis program will do much to inspire the next generation to

pursue STEM careers."

Dittmar said future space exploration missions will have important geopolitical ramifications as well.

"No longer in a race to the moon with the Soviets, United States leadership in space depends upon creating a foundation that provides other nations and a nascent space-based economy with security and assurance regarding our national intentions and long-term commitment to aspire, inspire and achieve – in short, to lead human space exploration and the development of space," Dittmar said. "If we do not do this, rest assured that someone else will. Space remains a strategic, competitive domain between nations."

The Space Launch System, Orion crew vehicle and Exploration Ground Systems form "the foundation upon which national goals in human deep space exploration will rest for the foreseeable future," Dittmar said. "Similar to the development of military capabilities, these are long lead-time national assets sustained as a guarantee against economic downturn, policy shifts and as a message to the global community."

Eric Stallmer, Commercial Spaceflight Federation president, suggested future U.S. space activities could diverge from those of the Apollo era by relying more on the innovation of commercial firms.

Infrastructure in low Earth orbit, operational elements of future lunar missions and most elements of the architecture necessary for Mars missions should either be purchased commercially or developed with industry through programs like the Commercial Orbital Transportation Services program, a public-private partnership to deliver cargo to the International Space Station, Stallmer said.

"NASA should specify clear, high-level, outcome-based requirements and allow entrepreneurs to innovate and create affordable and basic capabilities to meet essentially all the operational needs," he told the committee. "And NASA must pay for results, not effort on all developmental programs but the most esoteric technical >

Senators working on “bold” new NASA authorization bill

“The next 50 years have the potential to be even more consequential than the last.”

The chairman of the Senate’s space subcommittee says he’s working with colleagues on a “bold” new NASA authorization bill to direct the future of the agency’s human spaceflight program.

In his opening statement at a July 9 hearing of the Senate Commerce Committee’s space subcommittee on the past and future of NASA’s human spaceflight programs, Sen. Ted Cruz (R-Texas) said a new NASA authorization bill, yet to be introduced, would build upon a 2017 bill that called for human exploration of Mars.

“The next 50 years have the potential to be even more consequential than the last,” he said, stating that was why he was working with committee leadership “on yet another NASA authorization act to help continue to lay out a bold, visionary agenda for NASA and manned space exploration so that America continues to lead the world in exploring space.”

Cruz didn’t go into details about what the bill would contain, or when it would be introduced, but suggested it would support the administration’s current efforts to return humans to the moon

JEFF FOUST



U.S. Sen. Ted Cruz (R-Texas) said he’s working with colleagues in both parties on a NASA authorization act intended to guide the agency’s human spaceflight activities.

by 2024 as a step toward human missions to Mars, but also support commercial space activities. “We need a bold vision,” he said. “A vision that sees the commercial space industry thriving.”

Cruz said he was working with the subcommittee’s ranking member, Sen. Kyrsten Sinema (D-Ariz.), as well as Sens. Roger Wicker (R-Miss.) and Maria Cantwell (D-Wash.), the chair and ranking member respectively of the full committee, on the bill.

In a luncheon speech at the Future Space 2019 conference here July 10, Cantwell said one priority she had for the bill is “robust funding” for space activities the bill authorizes. She also called for “continued harmonization with NASA on the commercial side,” but didn’t elaborate on what specific measures she was seeking.

She also said the NASA authorization might be used to resolve concerns she and others in Congress have about the use of a 24-gigahertz band of spectrum

for 5G services. Both NASA and NOAA have warned that using that band for terrestrial 5G services could create interference with satellite measurements of atmospheric water vapor in a nearby band, which they argued could jeopardize weather forecasting.

“We have a challenge that we’re trying to help NASA with, which is not to give away spectrum that allows them and NOAA to have the best forecasting information,” she said.

The Senate, meanwhile, moved forward on another space-related bill. The Senate Commerce Committee favorably reported S.1694, a bill called the “One Small Step to Protect Human Heritage in Space Act,” intended to provide legal protections for the Apollo 11 and other historic lunar landing sites. The committee favorably reported the bill on a voice vote.

The bill requires any federal agency that licenses commercial lunar activities to make licensees follow recommendations issued

by NASA in 2011 regarding preservation of landing sites, as well as any updates to those guidelines. It also allows those agencies to assess penalties against licensees that violate those guidelines, but doesn’t give a specific dollar amount for such fines.

“The Apollo landing sites are the types of historic places that would be preserved for future generations if they were on Earth. As we mark the 50th anniversary of this giant leap for humankind, we must do everything we can to protecting these sites – particularly as more public and private entities look to establish a presence on the moon,” Sen. Gary Peters (D-Mich.), who co-sponsored the bill with Cruz, said in a statement.

“I urge my Senate colleagues to take up and pass this commonsense bill without delay to ensure that, as we ramp up our efforts to return to the moon, these important parts of history are safeguarded,” added Cruz in the joint statement. **SN**

“Apollonauts” reflect on lunar landing and return to the moon



Five of the “Apollonauts” who developed the Apollo Guidance Computer — Dan Lickly, Jim Kerner, Peter Kachmar, Peter Volante and Hugh Blair-Smith — pose with a model of the moon at Draper Labs to mark the 50th anniversary of Apollo 11.

The engineers who developed the computers that enabled the Apollo 11 lunar landing had little doubt the mission could be a success, and half a century later have advice for how NASA should return to the moon.

In the 1960s, the MIT Instrumentation Laboratory had a NASA contract to develop the Apollo Guidance Computer, one of the first portable digital real-time computers, used on both the command and lunar modules. Engineers took advantage of emerging technologies from that era, like integrated circuits, to develop a system that guided Apollo to the moon and to six successful landings on the lunar surface.

The facility, now known as Draper Laboratory

JEFF FOUST

and spun out after Apollo as a nonprofit organization, is marking the 50th anniversary of Apollo 11 with a “Hack the Moon” exhibition recalling its role in developing the Apollo Guidance Computer. At a media event at its headquarters here July 9, several of the engineers — dubbed “Apollonauts” by Draper — discussed their experiences developing the computer.

While the Apollo Guidance Computer pressed the limits of technology of the era, with the added constraints of schedule and size, those involved in the program said they never doubted they would be successful.

“The landing was kind of a nail-biter, but I don’t think anybody thought we weren’t going to do it,” recalled Peter Kachmar, a rendezvous engineer who still works at Draper today supporting work on the Trident missile’s guidance

system. “Whatever we set our minds to do at the lab, we can do. I had always felt it was going to be successful.”

That confidence, though, didn’t mean development of the computer and its software was without problems. While advanced for its time, the computer had only 36,000 words, or 72 kilobytes, of memory. “That’s why we rolled mission phases in and out, but they caused errors,” said Margaret Hamilton, who led the team that developed the software for the computer.

One such example, she recalled, was something her young daughter discovered playing with a model of the computer. Inputting commands to start a pre-launch program while in the middle of the mission caused the computer to crash. She then advised her management at MIT and NASA about the >

“The landing was kind of a nail-biter, but I don’t think anybody thought we weren’t going to do it.”

< > problem, and suggested a software fix to prevent it from happening.

They rejected her suggestion. “We just can’t do it,” she said they told her. The astronauts, they reassured her, “are too well-trained. It’s not going to happen.” It, in fact, did happen on Apollo 8, resetting the navigation system. Afterwards, she said management agreed to the software change to prevent that from happening again.

The limited capacity of the computer also led to major cuts in the software. Jim Kerner, a lunar module software engineer, said that at one point the software exceeded 150 percent of the available storage. On a day dubbed “Black Friday” NASA management directed major cuts to the software in order to fit into available storage.

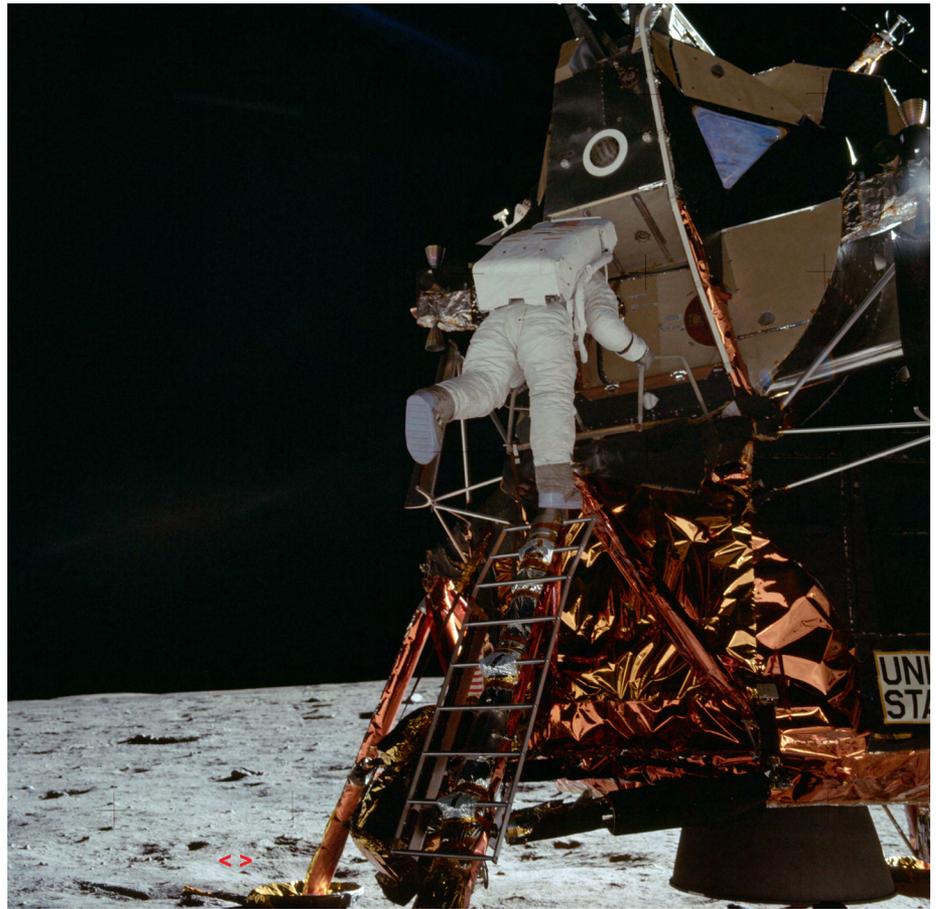
“Up until that point we all had the idea that the software would be self-contained and fly the mission without the help of the ground,” he said. “They chopped out a lot of the capability that was dear to hearts. Now the ground was preeminent, and we couldn’t fly the mission without the ground.”

Perhaps the best known issue with the computer system was the program alarms during the lunar module’s descent on Apollo 11. That was triggered by a rendezvous radar that was on during the lander’s descent, something the engineers said hadn’t been anticipated during development and testing of the computer.

Hugh Blair-Smith, who worked on the computer’s hardware and software, said that Buzz Aldrin had decided to leave the rendezvous radar on during descent, even though it wasn’t needed. That decision was based on the experience with Apollo 10, when the lunar module briefly lost attitude control as it prepared to return to the command module.

“He became doubly aware of the possibility that they’d have to abort and start using the rendezvous radar quickly,” he said. “He made sure in Apollo 11 that the rendezvous radar was as ready for instantaneous use as it could possibly be.”

The fact that the radar was on, as well as



Buzz Aldrin exits the Lunar Module “Eagle” and begins to descend the steps of the Lunar Module ladder as he prepares to walk on the moon.

what Blair-Smith called a “weird situation” with the power supplies on the spacecraft, meant that the radar was taking up computer cycles, triggering the alarm. “Buzz gets a lot of blame” for that, unfairly, he said. “Everything he had done was perfectly rational and very well founded on the events of Apollo 10.”

The engineers worked directly with a number of astronauts on the computer system. Dan Lickly, a software engineer on the system, singled out Neil Armstrong as someone particularly interested in the computer. “We were giving a lecture to a group of astronauts that was supposed to take one hour, and it took an hour and a half because Neil would just not stop asking questions,” he said. “We had no trouble communicating, because it was one geek to another. We got along fine.”

Without the Apollo Guidance Computer, engineers said the Apollo landings would not have been possible. “There wouldn’t have been a mission,” said Peter Volante, a software engineer. He recalled comments made by Chris Kraft at a symposium 10 years ago about Apollo. “Among the things he said in his talk that day was that it would

not have been possible to do Apollo without the modern digital computer.”

Computer systems have advanced remarkably in the half-century since Apollo, but the engineers who worked on the Apollo Guidance Computer still had advice for NASA as it returns to the moon with Artemis. One example of that advice is centralizing development.

“One of the most important features of the way the program was set up was that it was all here in one building,” Blair-Smith said. If someone ran into problems, “he didn’t send off an interdepartmental memo, he trots down two doors and asks me.”

Hamilton said that she’s still seeing the use of the “traditional lifecycle” approach to software engineering used in Apollo, which can be time-consuming and expensive. She called for the use of alternative approaches that avoid those problems. “It’s maybe going to happen, but it’s still going to take time,” she said.

“The most important thing is to understand exactly what miracles in project management were developed and worked,” Blair-Smith said. “We had plenty to complain about at the time, but it really was amazing.” **SN**

"A thriving, visible Artemis program will do much to inspire the next generation to pursue STEM careers."

< > challenges. Whenever possible NASA should award multiple, competitively chosen funded Space Act Agreements to commercial partners willing to put up private capital at their own risk."

If NASA adopts this model of partnerships and competition, the space agency will no longer pay for the "costly micromanagement and bureaucracy" of typical contracts awarded under Federal Acquisition Regulations, Stallmer said.

Homer Hickam, former NASA engineer and "Rocket Boys" author, suggested the United States take another approach to reducing the cost of space exploration. The United States should return to the moon and "set up shop to utilize its mineral wealth and discover all that is there," including possible evidence of life. "We're going to find a lot of water ice on the moon and in there may be evidence of life," Hickam said.

While he applauds the essential elements of the Artemis program, Hickam said NASA's lunar program "must make sense to the American people both economically and philosophically." If U.S. taxpayers agree to pay the up-front cost of future lunar missions, they should know that lunar exploration eventually will more than pay for itself, he said. "The riches on the moon should be gathered to boost our economy and thus put money in the pockets of all Americans," Hickam said. **SN**

NASA contractors support Artemis cost estimate

Companies involved in NASA's exploration program agree with a recent estimate by the head of NASA that landing humans on the moon by 2024 will require an additional \$20 billion to \$30 billion for the agency.

NASA Administrator Jim Bridenstine gave that cost estimate in a June 13 interview with CNN, saying that spending would take place over the next five years on top of existing NASA budget projections. He didn't elaborate on what that cost estimate covered or how it was developed. NASA has not provided additional details about that cost estimate or answered media inquiries about it.

At a panel discussion June 20 organized by the Space Transportation Association, executives with several companies involved in various aspects of what NASA now calls the Artemis program said that overall cost estimate appeared to be reasonable.

Frank Slazer, vice president for strategy and business development at Aerojet Rocketdyne, noted that many major elements of Artemis, including the Space Launch System, Orion and the lunar Gateway, are already included in those earlier projections. "One element that has not been in the budget so far was the lunar lander," he said.

Development of the lander, he said, would likely require most of that additional funding Bridenstine estimated was needed. "The lunar lander, if you go back to the Apollo era, was about \$30 billion" in president-day dollars, he said. "So that's probably about right if you want to think about developing a lander capability."

A recent study published by The Planetary Society, examining the historical costs of the Apollo program, estimated that the Lunar Module developed for Apollo cost



about \$23.4 billion to develop in 2019 dollars.

So far, NASA had requested only \$1.6 billion in additional funding for Artemis for fiscal year 2020. Of that, \$1 billion was earmarked for lunar lander work, with the rest going to SLS, space technology and science missions. That budget amendment, released May 13 but not yet taken up by Congress, cut several hundred million dollars from the Gateway program, reflecting the decision to develop only a "minimal" Gateway for supporting the initial 2024 landing.

Others noted that, besides the total amount of funding needed for Artemis, there's the question of how it will be spread out over five years. "The phasing of this is important," said Tony Antonelli, mission director at Lockheed Martin for the second flight of the Orion, formerly known as EM-2 and now called Artemis-2. Development programs usually have a funding profile that rises and then falls, although SLS and Orion have instead operated under much flatter funding profiles.

"We didn't follow the optimum funding phasing profile through development, so it took us longer and probably cost more to get to here," he said, adding the company was finalizing a

production contract with NASA for future Orion spacecraft. "But we're here now, so we can get to this production phase."

The panel came a day after a Government Accountability Office report that warned additional delays in the first SLS/Orion launch, Artemis-1, are likely. That launch is scheduled for June 2020 but the report said there is as much as 12 months of schedule risk to that date, which if realized would push the launch to June 2021. That could affect later launches, including the Artemis-3 mission in 2024 that NASA currently foresees as the one carrying astronauts to the Gateway, from which they would board a lander to go to the lunar surface.

Bill Beckman, director of NASA programs at Boeing, said that the company was making good progress on the SLS core stage, with the engine section now complete and undergoing testing. "We're still driving towards a 2020 launch" of Artemis-1, he said.

Antonelli said Lockheed has already received long-lead items needed for production of the Orion spacecraft for the Artemis-3 mission. "We're well on our way to keep the third mission of Orion, which will land folks on the moon, on schedule," he said. **SN**

JEFF FOUST

Q&A with presidential historian Douglas Brinkley

Apollo 11 memories ‘seared in my mind’

Beneath the Space Shuttle Enterprise within New York’s Intrepid Sea, Air and Space Museum, presidential historian and Rice University professor Douglas Brinkley sat down with reporter Doris Elin Salazar to chat about the Apollo 11 mission and his latest book, “American Moonshot: John F. Kennedy and the Great Space Race” (Harper, 2019).

The 50th anniversary of the first moonshot journey is weeks away, and during this June 14 interview, Brinkley offered both a historian’s perspective as well as a few personal anecdotes about being a boy and staying up late to watch the mission unfold on his television.

What’s something that you discovered in the process of researching the book?

One of the stories about going to the moon is that it’s all American men.

But there was a women’s pilots core: 13 women astronauts known as the Mercury 13, who went out to New Mexico and trained and passed all the endurance tests, and were ready to go into space. [NASA never formally accepted them as astronauts and the Mercury 13 nickname was bestowed on them decades later.] But due to that era of gender bias, women never got the opportunity. The Soviets beat us to putting the first woman in space. But by 1983, you have Sally Ride, and now we’re sitting under a space shuttle and in the new space era, women astronauts are abundant.

I wanted to make sure that I told the story of the Mercury 13 in my book. I’m asked a lot now, “Should we go back to the moon?” And I say, yes, in four or five years, but it needs to be with the first woman on the moon because I think that would be a great opportunity for our country to experience that and also it would generate a lot of national excitement.

DORIS ELIN SALAZAR



Neil Armstrong photographed his shadow on the moon after walking away from the lunar lander.

I’m wondering if you think about the international scope of sending people to the moon. We talk about NASA and the American ability to be able to send spacecraft these long distances, but I think this story also reaches a lot of people across the world.

Well, I’ll tell you, I teach at Rice University; that’s where John F. Kennedy on September 12, 1962, gave the famous speech, “we choose to go to the moon.” The point of that speech was public discovery, science, space as the new ocean.

I wanted to really write [in this book] more about the beginning; how humans [broke] the shackles of Earth, putting projectiles 62 miles (100 kilometers) up into the sky and beyond. That didn’t happen until World War II, and it was Germany that was the pioneer in early space exploration. So I write about what happened in Germany and then about the competition between the United States and the Soviet Union.

Going to the moon became sort of a proxy to not go to war. We had fought the Korean War, and we get mired into >

<> the Vietnam War. But space was presented as a friendly competition between two geopolitical adversaries.

Both the United States and Russia went gangbusters to try to be the first there. The fact that the United States did it is something that's celebrated in the U.S., because Neil Armstrong and the Americans were the first on a celestial body. But, our astronauts left on the moon medallions commemorating the Russians that died in the space program. So on the moon where Neil Armstrong's bootprints are, are memorials to Russian cosmonauts.

Now, ever since the United States went to the moon, many countries are participating in space. China has a robust program, Russia, Brazil, the European Union, Japan, and so it's really an international field. That's why after the moonshot, the big thing became the International Space Station.

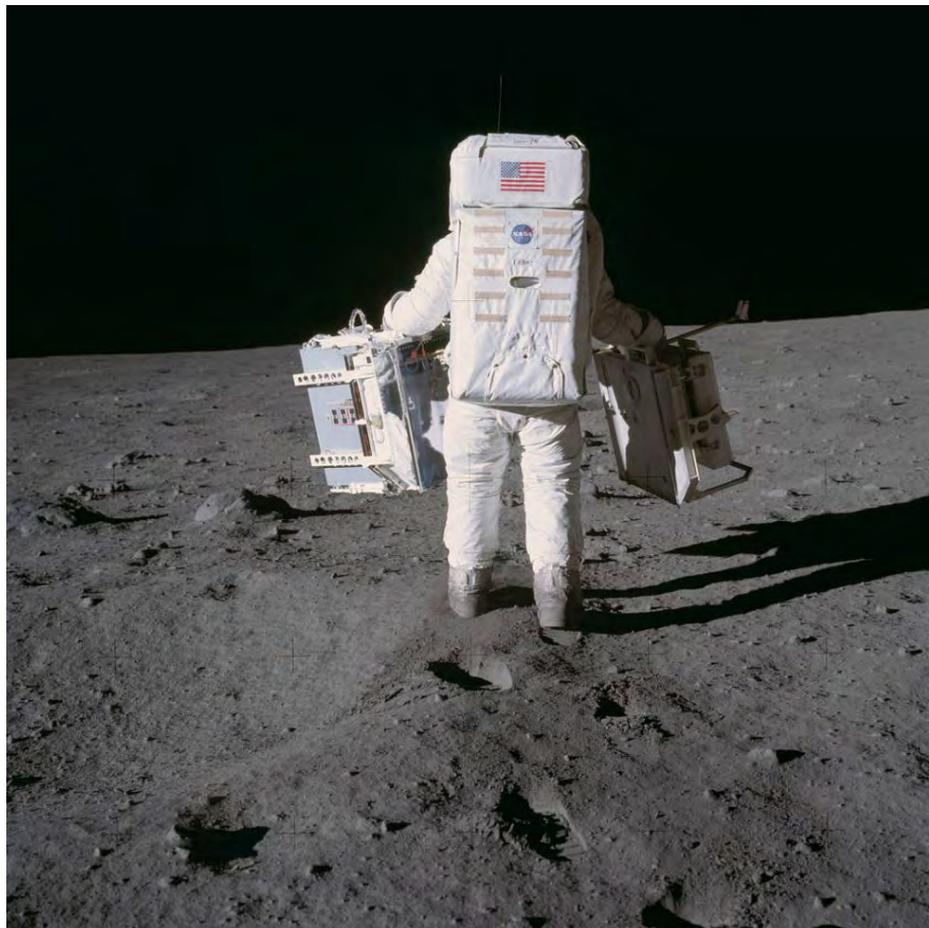
Today, Russian rockets are sending American astronauts into space. So it doesn't have a rivalry aspect to it. That might happen down the line, China and the United States might compete. Some people think the United States and Japan may go into space or Mars together. Who knows. But it's definitely global in scope. But back in the early days, it was more about two countries who had the money to get into i

NASA announced that it will be opening up the International Space Station to private astronauts. How do you think that may affect the future of spaceflight?

It's an exciting field. I once wrote a book on Henry Ford and the automobile world, called "Wheels to the World" (Penguin Random House, 2004), all about Henry Ford and Ford Motors.

At the World's Fair in St. Louis at the beginning of the 20th century, there were 100 auto companies trying to premiere the automobile. Ninety-nine are defunct. Only Ford Motors survived. So of all these people trying to go into space today, we don't know who the winners and the losers are. But there is a fierce competition between these companies to get U.S. government contracts and subcontracts.

What was the connection between John



In this image taken during the Apollo 11 mission, astronaut Buzz Aldrin moves toward a position to deploy two components of the Early Apollo Scientific Experiments Package on the surface of the moon.

F. Kennedy and the Apollo mission? What was it about that administration that made that possible?

U.S. presidents only have so much bandwidth, and they often get to pick one issue or two issues, which they turn into something that they care deeply about. John F. Kennedy picked space. Kennedy's timing was good because as a U.S. senator in the 1950s, he had complained that the United States was woefully ignorant in the field of teaching math and science.

So Kennedy was an early promoter of what we call STEM [science, technology, engineering and math] research at public schools and universities. And then also, the Soviet Union put the first satellite into space with Sputnik. And they put the first

creature into [orbit] with Laika. And yet the computer chip of today was really innovated by Texas Instruments in the late 1950s. NASA wasn't created until 1958. In 1960, Kennedy is elected. So when he's president, NASA's only a couple years old, and Kennedy's a beneficiary of new computer technology and new innovations.

What he did quite well was sell space. He gave great speeches and fundraised on Capitol Hill and turned it into a great, collective, American endeavor. There are very few presidents that are as good as orators as John F. Kennedy. He is still quoted all the time. So for a future president, they would first, A. have to pick space as being important, and, B. prioritize it. Now the Trump administration is making >

< > rumbles about going to the moon and Mars. But [because of] the Kennedy effect of the mid-1960s, 4.4 percent of our annual budget went into space for NASA. Today, it's a third of 1 percent.

Space is very expensive; you have to prioritize it. Right now the Earth needs some help. We're dealing with climate change, and we have oceans that are dying. And some people feel it's really a time for an Earthshot: that we need to work on saving planet Earth. NASA today is giving us our climate data. I mean, so it's all interconnected. It's about believing in scientific experts, trusting scientists, believing in empirical data, and Kennedy wanted to both explore space and do oceanography, mapping of the oceans and the like. So I think both of those fields — space and oceans — are really viable for a president that develops a passion for them and who can put them to the front of a very heavy national priority list. Anything in life is about where you're going to appropriate the money. If you have funds, you can do things. No funds, you can't.

And right now, the United States has a lot of debt and we're in a kind of strange political climate. So it's hard to galvanize [collective] public support.

What makes the 1960s era different from today?

Well, in the 1960s, we were still having the World War II hangover effect; you know, it's only 15 years after World War II ended when Kennedy ran for President. The United States' economy had been very tied to the federal government and private sector, working in collaboration on big projects in World War II. So it was easily transferable to take that energy into a Cold War battle to who's the first to the moon. Things have changed since then.

Yet what's consistent and, I think, has even grown, is public interest in space exploration. It may not be to the point that everybody's glued to their T.V., [as they were] watching Neil Armstrong walk on the moon, but space is a very robust field of endeavor and people from universities all over the country, all over the world, are engaged in space exploration. It's an exceedingly exciting area.

From a thousand-year perspective, we may be traveling this entire solar system



A colorful high-resolution mosaic of the full moon reveals slight differences in the chemical composition of the lunar surface.

in ways we can't even imagine today. But what's important about Armstrong and Apollo 11 and Kennedy's Apollo push was we did it, and finally humans were able to leave the shackles of Earth and go somewhere else. And that, in the scope of human history, is a large event. Maybe a thousand years from now, most politicians alive today won't be known; nobody's going to remember senators or congresspersons from today. But people will know the name Neil Armstrong. Not just because he's the first, but [he] became our representative human to leave Earth.

And it's a big accomplishment, but it was really the rocket engineers, computer specialists, astrophysicists; it was the scientific community that allowed Armstrong to go up there.

Do you, or anybody in your family, have memories of the Apollo 11 landing? Could you maybe share a little bit about the feeling?

I was eight and a half years old and I was living in Perrysburg, Ohio. And it was about 80 miles (129 km) or so from Wapakoneta, Ohio, where Neil Armstrong was from. So when you look at the whole planet, I happened to be living right down the road from where Neil Armstrong. I was eight and a half years old, so it was pretty exciting.

So you knew that at 8 and a half years old?

Yes, oh my god! My mom and dad were high school teachers so they were really in [to it]. We had space posters and memorize-your-planets and star-galaxy guides and a telescope, and we were pulled into it. And so it was a great memory not just [because of] my own excitement, but I remember my mother, who's now dead, how excited she was that we did it, [that] we went to the moon. And so it's those memories of that 8-day mission of Apollo 11 that are seared in my mind. Obviously it gets warped over time because [footage] gets shown over and over again from a few iconic moments.

But for me it was, like, an event because I got to sleep in my sleeping bag by the TV and stay up at weird new hours to watch different programming from it and see all that grainy black-and-white footage. And for my mother and father's generation, to them, it was so wild. They were born with no television ... in the 1930s. The fact that the United States is doing television images from the moon live into your living room in the middle of rural Ohio is pretty spectacular.

Hopefully, the 50th anniversary of Apollo 11 will make people appreciate the past, but also look at the moon and the stars, and aim for the future. **SN**

This story originally appeared on Space.com.

The Eagle has crashed

The top secret UPWARD program and Apollo disasters

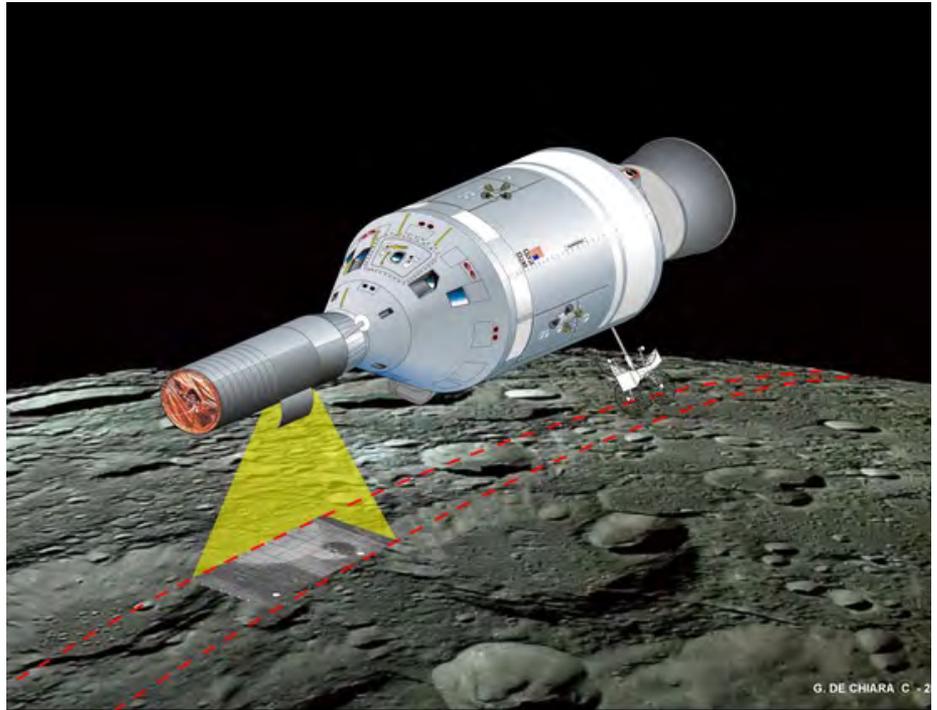
During the height of the race to the moon, NASA considered the possibility that the Apollo 11 Lunar Module with Neil Armstrong and Buzz Aldrin aboard could crash on the surface without leaving sufficient telemetry about what had gone wrong. In such a situation, NASA might have to send a high-powered camera, derived from a top-secret reconnaissance satellite, to image the crash site, a sort of secret crash scene investigation. Of course, that never happened, but NASA had nearly finished the hardware to accomplish the mission by the time they canceled the program in summer 1967.

Declassified documents indicate that NASA and a secretive organization known as the National Reconnaissance Office (NRO) collaborated on the classified UPWARD program. The goal of UPWARD was in fact to look down from lunar orbit and photograph the moon in very high resolution in preparation for the lunar landings. But the project made some in the U.S. intelligence community nervous, and once the immediate requirement for it disappeared, the two agencies argued about its continuation.

INSURANCE POLICY

During the early planning phases of the Apollo lunar landing program, NASA engineers were concerned that they knew relatively little about the lunar surface. Although most scientists dismissed suggestions that the moon might be covered in fine powder that could swallow a Lunar Module, they were primarily guessing about the qualities of the surface. Considering that the astronauts would be flying an untested and finicky vehicle, they needed as much data on the lunar terrain as possible. So, NASA undertook a series of precursor robotic missions that would characterize

DWAYNE DAY



The Lunar Mapping and Survey System would have photographed the Moon at high resolution.

the lunar surface, providing vital data on the size of surface features, the smoothness of terrain, and especially the slope of the terrain. NASA stripped much of the science from the Surveyor program and directed it toward measuring surface characteristics in support of Apollo, and started the Lunar Orbiter program to photograph potential landing sites.

Lunar Orbiter, which began in 1962, benefited from access to classified spy satellite technology because of an agreement between NASA and the NRO. But in 2010 the government revealed that NASA and the NRO had a second agreement to cooperate on a backup plan to Lunar Orbiter to provide the data necessary for conducting lunar landings, and actually

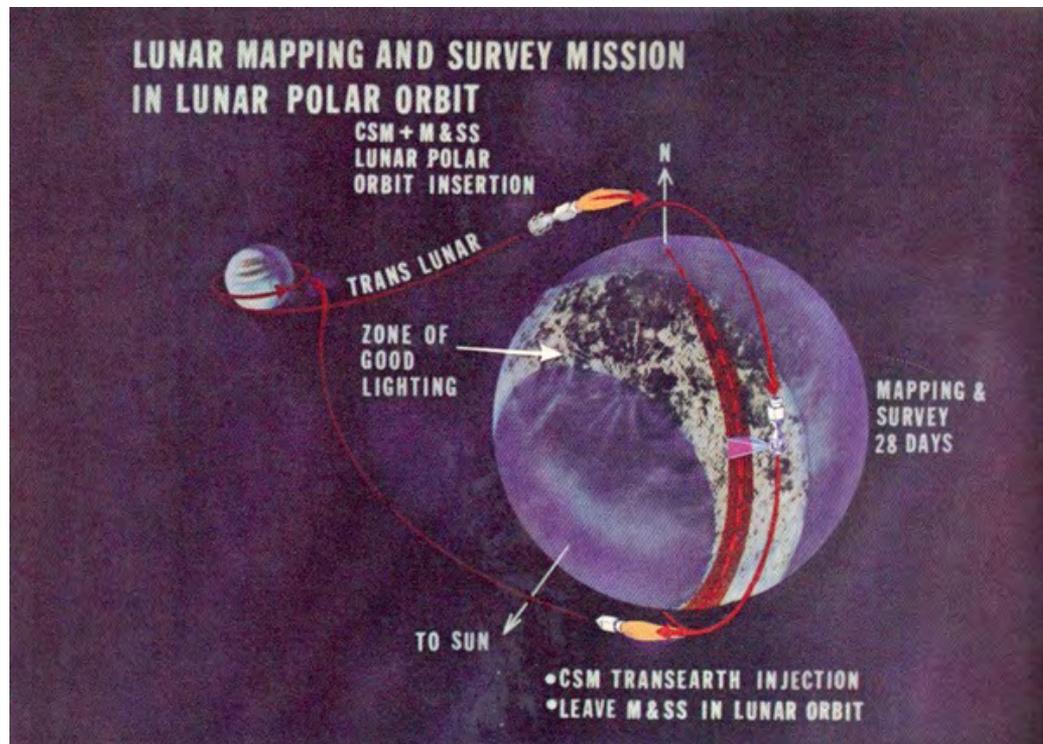
started construction of hardware. Unlike Lunar Orbiter, this hardware would be operated by Apollo astronauts in lunar orbit.

The backup project was known as the Lunar Mapping and Survey System, or LM&SS (often without the ampersand, and sometimes also known as the Apollo Mapping and Survey System.) NASA and the National Reconnaissance Office signed an agreement on LMSS in April 1964, when Lunar Orbiter was still in its infancy. In May 1964 NASA transferred \$800,000 to the Department of Defense to cover contractor studies regarding which existing NRO camera systems might be useful for Apollo. The people studying the problem quickly decided upon the GAMBIT-1 reconnaissance camera, which had first entered service in summer 1963 >

< > achieving high-resolution from low Earth orbit. GAMBIT-1 also had the designation KH-7. At the moon, the camera could be used at 30 nautical miles (56 kilometers) altitude to provide high-resolution images of the ground, or from 200 nautical miles (370 kilometers) altitude to provide broader area coverage. The new program was given the classified code name UPWARD, which never appeared in NASA documents.

The initial plan called for mounting the large GAMBIT-1 optics system in Scientific Instrument Module (SIM) bay No. 1 of the Apollo Service Module. Contractors would build four test units and two flight units for \$36 million. But after conducting a detailed study, the NRO decided to abandon plans to try to modify the camera system for the SIM bay and instead chose to use the camera inside GAMBIT's Orbiting Control Vehicle (OCV), a cylinder 18 feet (5.5 meters) long and 5 feet (1.5 meters) in diameter.

The GAMBIT-1 was, at the time, the most powerful camera system ever carried into space. It had a 44-inch (112-centimeter) primary mirror and a 77-inch (196-centimeter) focal length. The new plan was to carry the OCV with its powerful camera system along with the Apollo command and service modules atop a Saturn V rocket, with the OCV in the compartment reserved for the Lunar Module. The Apollo CSM would detach from the stack, turn around 180 degrees, dock with the OCV, and pull it free. Instead of a Satellite Recovery Vehicle at the front of the spacecraft, there would be a docking adapter, and inside the unpressurized spacecraft forebody would be the film takeup reel. After the reconnaissance mission was over, Apollo astronauts could then depressurize the capsule, open the hatch,



Artist concept from a 1968 encyclopedia showing the LMSS photographing the Moon. The existence of the LMSS was unclassified, although details were secret. Despite this, the LMSS program was overlooked by most histories of the Apollo program.

reach into the OCV, and detach the film takeup reel—sealed to prevent accidental exposure—and pull it back into the Command Module, all without ever leaving their spacecraft. After they resealed the hatch and repressurized the Command Module, they could detach the OCV and head home.

The GAMBIT-1 camera was manufactured by Kodak. Lockheed built the Satellite Recovery Vehicle, which was not needed for the UPWARD mission. It also built the workhorse Agena upper stage that placed the GAMBIT-1 in orbit and also was not needed. The OCV provided guidance and stabilization for the GAMBIT-1 and was manufactured by General Electric. But the LMSS would stay attached to the Apollo spacecraft and did not require the OCV's services.

In June 1965, Lockheed

won the contract to adapt the camera system for Apollo use. Lockheed was responsible for the film takeup system inside the Satellite Recovery Vehicle, and this would have required modification so that it could be handled by an astronaut. By the fall of 1965, the system design was finalized. Lockheed would also provide the shell that encased the camera system, based upon the shell that the company was producing for the upgraded GAMBIT-3 reconnaissance satellite. Thus, the GAMBIT-1 optical system would be mounted within a GAMBIT-3 shell.

Lockheed's contract required that it deliver the first UPWARD unit in July 1967, with a flight test in low Earth orbit in December. Although it was not until 1967 that the Apollo program developed the Apollo A thru J

designations for the different steps in the program, an Earth orbit test would have essentially been the equivalent of an Apollo D class mission. It is difficult to speculate which Apollo mission number or crew would have flown this mission in late 1967. At least one of the missions would be conducted in Earth orbit to test the equipment. But after that mission, the next one would involve launching a Saturn V to the moon.

LUNAR ORBITER TAKES FLIGHT

As work was progressing on these top-secret spacecraft for Apollo, NASA began launching the Lunar Orbiter missions. Lunar Orbiter I launched in August 1966, followed by Lunar Orbiter II in November 1966. Both missions were successful, and a NASA official concluded that these >

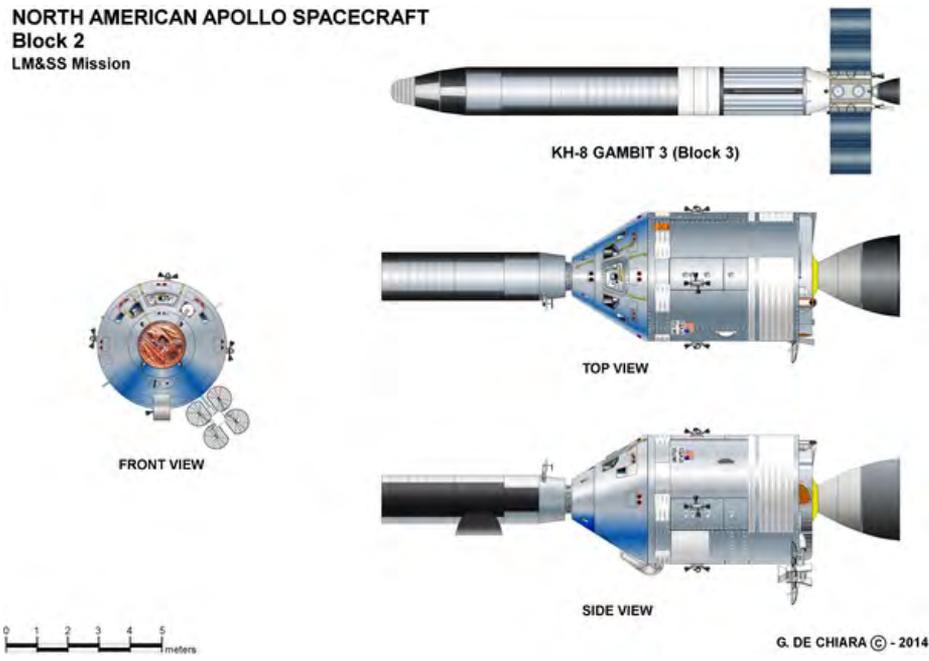
< > missions had “certified” several Apollo landing sites. But not everybody in NASA agreed, with several persons arguing that the Lunar Orbiter photographs had not provided sufficient data on the slope of the terrain at the potential landing sites.

In January 1967, the Apollo 1 fire dealt a major setback to the program and the schedule. As NASA investigated the fire and determined how to recover from it, this provided a pause that allowed those who were overseeing the LMSS to consider its future. It also exposed a rift between those at NASA who saw LMSS as a powerful tool that the civilian space agency could use, either at the moon or in Earth orbit, and those in the secretive reconnaissance community, who wanted to preserve the secrecy that surrounded their activities, which they considered vital to national security.

By April 1967, NASA Associate Administrator Robert Seamans, who had been the primary point of contact with the National Reconnaissance Office, discussed the future of the Lunar Mapping and Survey System program with DoD and NRO officials. Seamans had also ordered a comprehensive review of basing the landing decision on the imagery returned by Lunar Orbiter. DoD and intelligence community officials discussed three options: cancellation, continuation without testing in Earth orbit, and continuation with testing in Earth orbit. The Earth orbit testing option would have been particularly problematic because it would have resulted in the production of possibly unclassified high-resolution images of the Earth and attracted a great deal of attention to the classified reconnaissance program.

Seamans also proposed an additional option of converting the LMSS to scientific exploration of the moon, presumably for an Apollo mission after the initial lunar landing. For the intelligence community, the problem with Seamans’ proposal was that it still would have required publicly revealing the existence of the LMSS and its powerful optics system, raising potentially embarrassing questions about the nation’s top-secret reconnaissance program. In addition to the LMSS hardware, NRO and NASA officials had drafted a cover story and procedures for revealing the existence of the camera system. Intelligence community officials were uncomfortable with any public acknowledgement even of the existence of satellite reconnaissance, and would have

NORTH AMERICAN APOLLO SPACECRAFT
Block 2
 LM&SS Mission



The Lunar Mapping and Survey System, under the classified code name UPWARD, was derived from the GAMBIT-1 camera system and the GAMBIT-3 control vehicle. It would have been carried around the Moon by an Apollo spacecraft.

been completely opposed to revealing any information on satellite cameras that was not vital to the success of Apollo.

In the meantime, Lunar Orbiter III had flown in February 1967, and Lunar Orbiter IV had flown in May. Both returned useful pictures, further undercutting the requirement for the secret UPWARD program

VANISHING REQUIREMENT

The original justification for LMSS was, in the words of one NASA official “a backup Apollo site certification capability in the event of Surveyor or Lunar Orbiter inadequacies.” But by spring 1967 it was no longer required for this role. Some at NASA believed that it could accomplish other missions.

By June 1967, four locations had been certified as acceptable landing sites for the Lunar Module, and the last Lunar Orbiter, if successful, would certify four more landing sites. There was discussion within NASA about ending the LMSS, and by late June there were internal memos about the future requirement for the camera system. Apollo officials were reluctant to give up the system and proposed several reasons for keeping it. One reason was that until astronauts had actually landed on the moon, they would

not know how good the Lunar Orbiter data was compared to the actual landing site. The more powerful LMSS might still be required. In addition, the early landing sites were all in relatively easy—flat and smooth—locations. However, NASA was considering more challenging landing sites for later in the Apollo program, meaning that better photography might be required.

PHOTOGRAPHING A CRASH SITE

By this time those working on the program had suggested another use for the LMSS: “a quick-reaction photographic capability to survey accidents that might occur on the lunar surface.” But in late July, Seamans concluded that the LMSS “did not have the required flexibility” for this mission because it would require a separate Saturn V flight considerably later than an accident. Seamans therefore determined that the program should be terminated and the LMSS hardware stored until NASA could decide what to do with it.

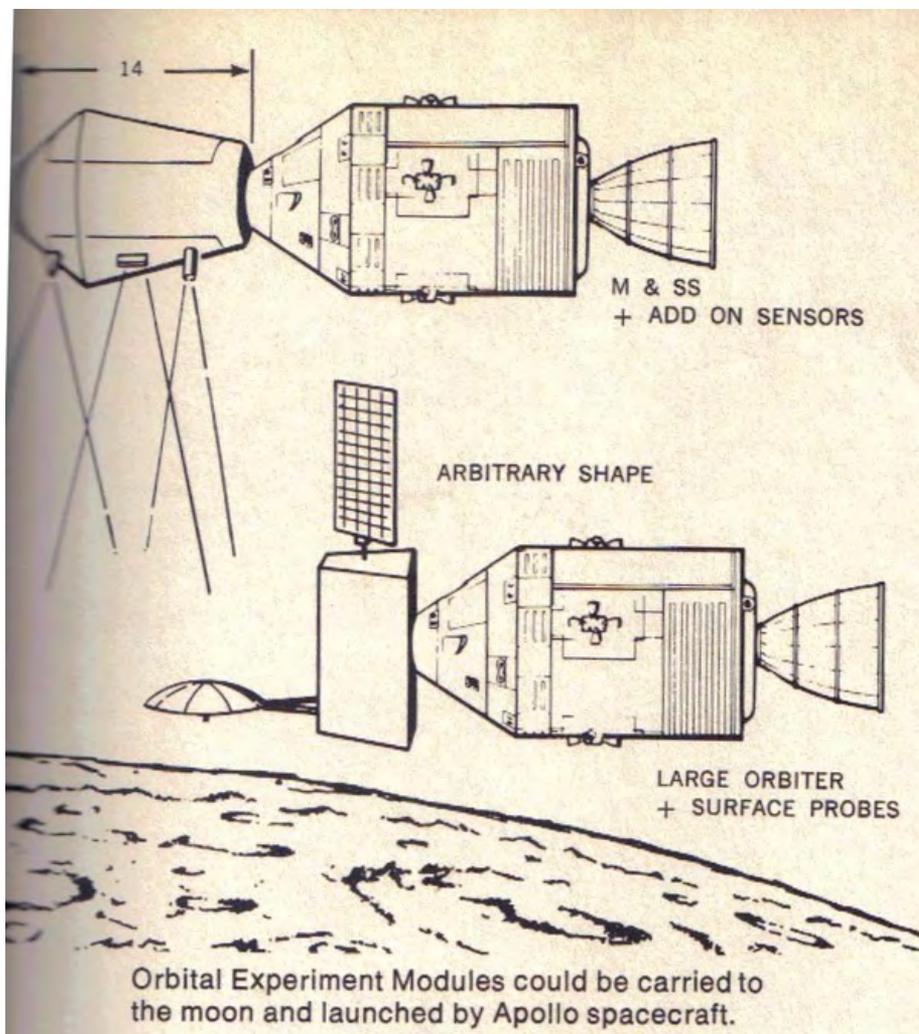
The discussion also convinced Seamans that it might be useful to have a low-cost way of photographing equipment on the lunar surface in event of an accident, especially for the first landing mission. >

<> He wrote “ideally, the CSM should be able to obtain meaningful information about any LM accident before returning to earth. While the possibility of an incident in which photography would be the only data available for analysis is considered very remote, I feel it would be worthwhile to have a simple high-quality CSM photographic system available before the first lunar landing.” If a Lunar Module crashed, it would be the responsibility of the surviving astronaut, the Command Module pilot, to photograph the accident site from orbit before heading home, all by himself.

In July 1967, Seamans sent a memo to NASA's Associate Administrator for Manned Space Flight indicating that NASA could not justify continuing the LMSS. He also asked for an assessment of photographic reconnaissance systems that could perform the landing site analysis mission. These included handheld cameras in the Command Module, Service Module-mounted camera systems then in the planning stages, and Block I and Block II LMSS systems. Seamans asked for a rapid assessment of these capabilities and the requirement.

Seamans added that he would also like to discuss “the possible uses, for other missions than lunar mapping and survey, of the two sets of LMSS equipments about to be delivered, so that we can achieve maximum benefit from our investment to date.” This opened a whole new can of worms for the National Reconnaissance Office. The Director of the NRO, Alexander Flax, was not happy with the idea of NASA continuing the LMSS if it was no longer needed to support Apollo.

There was an additional problem: Kodak was discontinuing the GAMBIT-1 camera system in favor of the much more powerful GAMBIT-3, also designated the KH-8. The first GAMBIT-3 had flown in July 1966. The last GAMBIT-1 launched in June 1967 and the NRO was no longer paying for it. With the GAMBIT-1 retired, any work on camera systems derived from GAMBIT-1, like that used for the LMSS, would have had to bill all the costs, including overhead, to the LMSS program, meaning NASA's costs would rise substantially. On July 25, 1967, Seamans informed senior NASA officials that he planned on canceling LMSS. But he waited until after the successful launch of Lunar Orbiter V in August 1967 before informing the NRO of his decision.



Notional illustration from a 1968 encyclopedia showing the LMSS

PRESERVING UPWARD

Seamans ordered that the classified hardware produced for the Lunar Mapping and Survey System be placed in storage awaiting further decision on what to do with it. This consisted of four units in various stages of development, including two that were nearly complete. Apparently, somebody at JPL later again proposed that the camera system be carried on lunar landing missions, but the system was simply too big and heavy to be carried with any mission that included a Lunar Module.

What happened to the stored hardware remains unclear. The hardware was classified. At least initially it would have been stored by the contractor—either Lockheed or Kodak. But contractors do not store

equipment for free, and at some point NASA probably either transferred the remaining LMSS hardware to the NRO, or ordered it destroyed. Even if it was transferred to the NRO it may have been later destroyed as surplus. However, two film takeup canisters, which would have been retrieved by the astronauts with the exposed film inside and returned to Earth, were apparently preserved and still exist. Although they are not currently on public display anywhere, they would be good additions to a museum able to properly place them in context, like the Kansas Cosmosphere. This article contains the first ever published photos of this hardware.

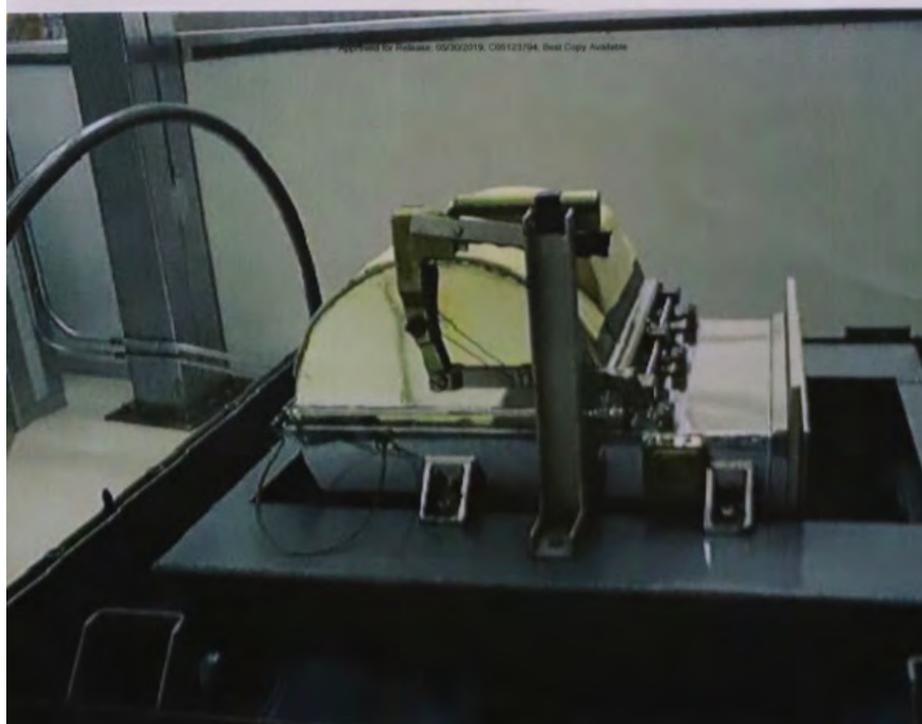
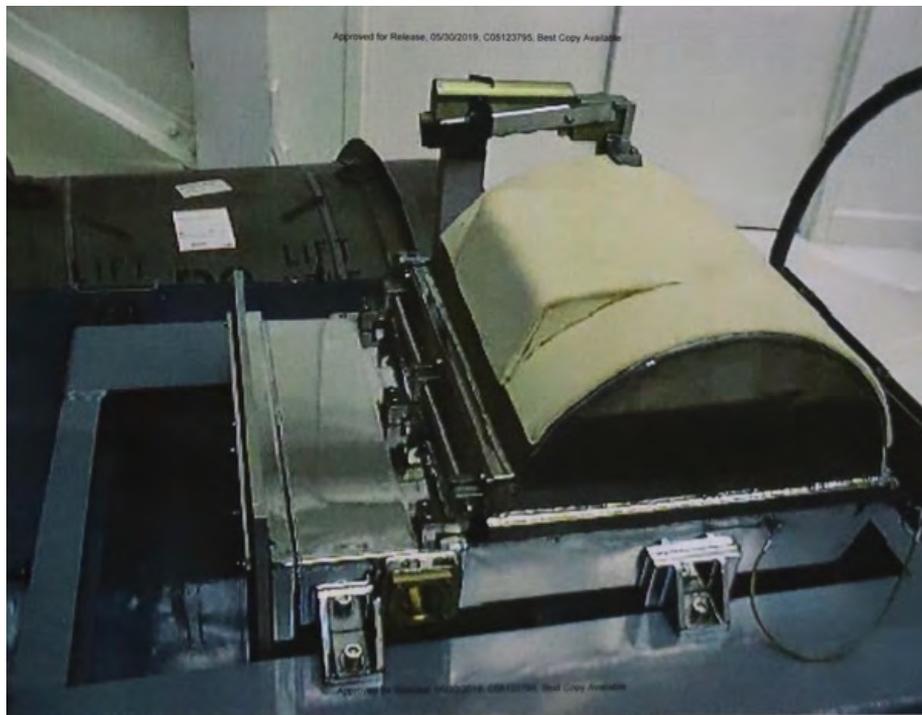
NASA also considered using the LMSS as part of a space station in Earth orbit. Some unclassified NASA documents included >

<> simple line drawings of the exterior of the Lunar Mapping and Survey System, although no description of it. The LMSS was depicted as a large cylinder that would be connected to the Apollo CSM docking port and then maneuvered into place on the space station. A couple of illustrations depict it inside a large truss structure that would hold it inside the Saturn Launch Adapter. Other illustrations show no truss structure. Although some kind of structure would have been required to carry the LMSS inside the Saturn, at the time engineers had not decided if it was possible to pull the large camera out of the truss, or if they would leave the truss attached. For Earth orbit operations the mass penalty would have been unimportant, but the truss would obscure the Command Module pilot's vision and made it harder to attach to the space station.

The code name UPWARD was classified, along with technical details of the equipment, but the existence of the LMSS program was not classified. NASA did nothing to publicize the project during Apollo. It is not mentioned in official histories or the hundreds of popular books about the Apollo program. The only known contemporary mention of it is very obscure: in the *Above and Beyond Encyclopedia*, published in 1968. The encyclopedia entry noted the LMSS would be carried in the Saturn Launch Adapter in place of the Lunar Module and would consist of a "high resolution survey camera and a moderate-resolution mapping camera in combination with a stellar index camera." The book stated that 75 pounds of film would be exposed and then retrieved by an astronaut and added that "four LMSS devices are being developed." The entry was accompanied by two illustrations, one showing the spacecraft in a lunar polar orbit, although this may not have been the actual planned orbit. Obviously, whoever wrote the entry obtained the information from NASA, because it was an accurate description of the program. But other space historians were apparently unaware of LMSS for decades after the program existed.

What the UPWARD/LMSS story tell us is that 50 years after the moon landing, the story of Apollo is far from complete. There may still be more secrets of Apollo lurking in the darkness. **SN**

Dwayne Day is interested in hearing from anybody who was involved in the UPWARD/LMSS program. He can be reached at zirconic1@cox.net.



Newly declassified photos of the only remaining hardware from the UPWARD program. These film takeup canisters would have been recovered by an Apollo astronaut at the end of the photography mission.

Intrepid Museum honors Apollo software engineer Margaret Hamilton



Margaret Hamilton accepted an award at the Intrepid Museum in New York on May 23, 2019.

The Intrepid Museum in New York City kicked off a summer of Apollo events May 23 by honoring software engineer Margaret Hamilton with the institution's Lifetime Achievement Award.

Hamilton led the team of programmers who ran the computers on both the command module and the landing module of the Apollo 11 mission. When she began her career, the field was so young that the term software engineering did not yet exist; Hamilton coined it herself.

"The software experience itself was at least as exciting as the events surrounding the mission," Hamilton said during her acceptance speech at the awards ceremony. "As developers, we had the opportunity of a lifetime, to make every kind of

error humanly possible."

All those errors were made before Apollo 11 launched, to be clear. As Hamilton and her colleagues were working on the project, they were always conscious of how well-tuned the software needed to be.

"Astronauts' lives were at stake. It had to work. The first time," Hamilton said. "Not only did it have to be ultrareliable, it would need to be able to detect an error and recover from it in real time. Problems had to be solved [that programmers had] never solved before."

But Hamilton also recounted a key turning point of the mission, just as Neil Armstrong and Buzz Aldrin were preparing to touch down. "Everything was going perfectly; Walter Cronkite was reporting the mission in great detail," she said. "All of a sudden, something totally unexpected happened. Just as the astronauts were about to land

on the moon, the software's priority displays interrupted the astronauts' normal mission displays and replaced them with priority alarm displays to warn them there was an emergency."

The alert was triggered by a switch that was misaligned; the astronauts fixed it and landed safely. "The Apollo 11 astronauts became the first humans to walk on the moon," Hamilton said. "Our software became the first software to run on the moon."

That moment was pivotal for more than just the field of computer science, former NASA astronaut Mike Massimino, who presented Hamilton with the award, noted during his introduction. "It is because of developments like this and pioneers like Margaret that the United States was able to continue its work that led ultimately to a reusable spacecraft, the space shuttles, which I had the privilege to fly on twice," he said. "I and all of my astronaut colleagues owe you a personal debt of gratitude."

During her remarks, Hamilton also shared memories from her career before joining the Apollo effort, including how she began her computer science work by developing programs to better predict the weather. She also touched on her software engineering work on MIT's Semi-Automatic Ground Environment (SAGE) project, which helped military personnel detect enemy planes.

That program ran on a notably cantankerous computer, she said. "The machine was huge; if your program crashed, the computer would tell on you with sirenlike and foghornlike sounds throughout the building that everybody could hear and

"Astronauts' lives were at stake. It had to work. The first time."

flashing lights that everyone could see," Hamilton said. "Everyone would come running to find out who the guilty one was. We used a Polaroid camera to take a picture of the bug together with the person who caused it."

Hamilton is still an active software engineer, pursuing a new system that prevents errors before they occur, rather than addressing them after they arise. That work builds directly on her experience with the Apollo program, she mentioned during her remarks.

"Whatever success I may have experienced, much of it was because I was in the right place at the right time with the right opportunities and the right people," Hamilton said. "I had the benefit of beginning with no preconceived notions. Much of the credit goes not only to those I have learned from, but also to the errors I have had the opportunity of having had some responsibility in their making, without which we would not have been able to learn the things we did."

Those glitches and mistaken pathways were crucial, she continued. "The errors showed us what to do and where to go, each holding answers to questions we had not thought of asking," Hamilton said. "They told us how to exist without them." **SN**

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MEGHAN BARTELS

Apollo 11 anniversary coins take ‘small step’ to space and back



NASA astronaut Christina Koch displays a U.S. Mint Apollo 11 50th Anniversary commemorative coin on board the International Space Station in May 2019.

A curved tribute to the 50th anniversary of the first moon landing recently completed a trip around the curvature of the Earth many times over.

Two commemorative coins from the United States Mint were flown on board the International Space Station for 28 days. The domed, half dollar coins traveled to orbit and back on a SpaceX Dragon cargo spacecraft.

NASA astronaut Christina Koch displayed one of the two coins in a video recorded for the Mint.

“Fifty years ago, we took our first small steps onto the moon and made a giant leap that united and inspired the world. NASA accomplished this 50 years ago for all of humankind,” Koch said, referencing the July 1969 lunar landing. “We are honored by the U.S. Mint issuing this commemorative coin celebrating the accomplishment of NASA, our nation and every human who dares to dream.”

Gold, silver and clad coins were struck to mark the half-century since astronauts Neil Armstrong, Buzz Aldrin and Michael Collins achieved the world’s first moon landing mission in July 1969. The commemoratives are only the second coins in the U.S. Mint’s

history to be curved.

The coins’ reverse, or tail’s side, is convex, resembling the outward curve of an astronaut’s helmet and feature a design based on an iconic photograph of Aldrin’s visor, showing the lunar module “Eagle,” the American flag and Armstrong on the moon’s surface.

The obverse, or head’s side, is concave, curving inward to the engraved image of Aldrin’s boot print in the lunar soil. The design also features the names of the three NASA human spaceflight programs that led up to the first moon landing: Mercury, Gemini and Apollo.

“As with all U.S. Mint commemorative coins, they are made for all and available to all,” Koch said.

In January, the U.S. Mint released the coins for sale in half dollar, dollar and five dollar denominations, in proof and uncirculated finishes, with limited editions of 50,000 to 750,000. Since then, the U.S. Mint has partnered with Australia’s and Spain’s mints to issue coin sets recognizing the tracking stations that supported the Apollo 11 mission.

Proceeds from the U.S. Mint’s sale of the Apollo 11 50th Anniversary coins benefit three space-related organizations that work to preserve space history and promote science education: the Astronauts Memorial

Foundation, the Astronaut Scholarship Foundation and the National Air and Space Museum’s “Destination Moon” gallery, scheduled to open in 2022.

The Astronaut Scholarship Foundation, which awarded Koch a scholarship when she was an undergraduate studying electrical engineering and physics, provided Sam Scimemi, director for the International Space Station at NASA Headquarters, with the two coins that were flown into space.

The proof-quality, clad half dollar coins were launched to the station May 4 and returned June 3 aboard SpaceX’s CRS-17 mission. Now back on Earth, one of the coins will be displayed by the U.S. Mint.

The second coin “will go on display in our upcoming Destination Moon exhibition,” the National Air and Space Museum announced on Twitter.

Koch said that she hopes the trip to the International Space Station will be just the first launch for the Apollo 11 coins.

“These coins have made the small step here, to the International Space Station, and I hope when we are building a sustainable presence on the moon and make that next giant leap onto Mars, the coins will go along on our journey as a reminder of all the hard work and sacrifice that moves us all forward,” she said. **SN**

ROBERT Z. PEARLMAN

HBO relaunches 'From the Earth to the Moon' with new HD visual effects



Ted Levine (right) and Gary Cole portray Apollo 14 crewmates Alan Shepard and Ed Mitchell in HBO's "From the Earth to the Moon." The 12-part miniseries has been digitally remastered for the 50th anniversary of the first moon landing in July.

HBO is once again launching its viewers "From the Earth to the Moon." To celebrate the 50th anniversary of the first lunar landing in July, the network is presenting an encore of its Emmy-winning 1998 miniseries that chronicled NASA's Apollo moon missions. All 12 hourlong episodes have been digitally remastered to be in high definition.

"To celebrate the [Apollo 11] anniversary, been replaced with brand-new CG [computer graphic] effects that are based on reference models from NASA," HBO announced June 25.

Starting July 15, all 12 digitally remastered episodes will be available to watch on HBO Go, HBO Now and HBO On Demand. Then, on July 20 — the 50th anniversary of the first moon landing — HBO2 will air a marathon of the complete series.

HBO is also releasing "From the Earth to the Moon" on Blu-ray on July 16, with remixed audio in Dolby ATMOS and an "Inside the Remastering" featurette, which provides a behind-the-scenes look at the "decision-making process and work put into updating and replacing the previous CG effects."

Co-produced by Tom Hanks, Brian Grazer, Ron Howard and Michael Bostick, the same team behind the 1995 feature film "Apollo 13," HBO's "From the Earth to the Moon" follows the early years of the U.S. space program through the six missions that

landed 12 Americans on the moon.

With a budget of \$65 million, "From the Earth to the Moon" took over two sound stages at Disney-MGM Studios in Orlando, Florida, and was filmed at NASA's Kennedy Space Center at Cape Canaveral and Edwards Air Force Base in California, among more than 100 other locations.

"NASA allowed production access to many areas and buildings at the Kennedy Space Center that were actually used during the space program, including the launch pads, the vehicle assembly building, astronaut corridors, NASA medical offices and Mercury Command Center (Mercury Mission Control)," said HBO.

Each episode begins with an introduction by Hanks and features a crew of well-known actors, including Adam Baldwin, Bryan Cranston, Tim Daly, Cary Elwes, Sally Field, Dave Foley, Al Franken, Tony Goldwyn, Mark Harmon, Elizabeth Perkins, Kevin Pollak, Stephen Root, Alan Ruck, Peter Scolari and Rita Wilson.

The miniseries' directors and writers included David Frankel, Graham Yost, Frank Marshall and the late Al Reinert.

"From the Earth to the Moon" was based on Andrew Chaikin's 1994 book, "A Man on the Moon: The Voyages of the Apollo Astronauts." Apollo 15 moonwalker David Scott served as consultant.

SN — Robert Z. Pearlman

THEN & NOW 1969 vs. 2019

We're still waiting for flying cars and colonies on the moon, but a lot has changed in the 50 years since Neil Armstrong, Buzz Aldrin and Michael Collins made history on July 20, 1969. This Space Foundation infographic summarizes some of the differences.



Commentary | Tom Zelibor

What Will Be Different Next Time



Final systems checkout for NASA's Lunar Module (LM-5) are conducted in the Open Bay Area of the Manned Spacecraft Operations Building.

America is returning to the moon. In May, NASA announced the Artemis program, which sets an aggressive timeline for placing astronauts on the lunar surface by 2024. Half a century after Neil Armstrong and Buzz Aldrin took their first “small steps,” we’re going back with all the wonders of 21st century technology, but this time, things will be different.

Thinking back to July 1969 when I was a teenager in Dayton, Ohio, I recall a summer of inspiration. Apollo 11 expressed clearly that when people come together to work on a common goal, it is not only achievable—it is transformational.

In watching the fuzzy, black and white images on the TV screen in my parent’s

living room, it was easy to see myself reflected in the adventure. Growing up, the astronauts that traveled to space looked like me, and the people who powered and guided those missions looked like my dad and so many other fathers in my neighborhood. That is, the first astronauts on the moon and many of the people who sent them there were Caucasian and male.

With that, not everyone saw themselves reflected in space exploration the way I did. And that is where the new Artemis program can do something Apollo did not.

NASA Administrator Jim Bridenstine has already committed that an American woman will be among the Artemis astronauts. That commitment to diversity is more than overdue, and it is one

example of how this moon program can be an even greater source of inspiration and collaboration than Apollo. But there is another reason to insist on inclusivity in this modern moon program. Even with all of today’s breakthrough technology, this time going to the moon will be a group marathon, and not the singular sprint of generations before.

We’re already seeing the first steps of this methodical mindset coming together. The Lunar Gateway, along with all of the proposed step-by-step support missions and technology demonstrations are defining the first miles of this marathon. This lunar trek will also have a much wider array of domestic, international, government and commercial providers that can



A NASA artist's concept of a lunar ascent vehicle for the U.S. space agency's Artemis effort to return astronauts to the moon by 2024.

make every stride along the way possible. While some may question and deservedly challenge having such a distributed network of contributors, the dividends of job creation, technology transfer, expanded entrepreneurship, international partnerships, shared research and development, and more create wider opportunity than any other effort on the planet.

Want proof?

Fifty years ago, there were two nations competing in space for the first landing on the moon. While doing that, both countries were pioneering technologies to give themselves whatever strategic and competitive advantages they could.

Fifty years later there are 75 nations with spacecraft in continual operations above us that connect every continent, infrastructure and piece of our national and international security, and economy.

You don't have to be a military tactician to know that higher ground always gives greater opportunity.

For as much as the 50th anniversary of Apollo celebrations will focus on the men that went to space, every member of those legendary crews would tell you, no one reaches space alone. Apollo demanded

thousands of minds, millions of hours of work, and billions of dollars in investment. Artemis will require even more of the same, but it will distribute those burdens and opportunities among a far larger and more capable pool of talent than anything Apollo ever possessed or imagined.

When you structure complex endeavors in this way, it creates broad ownership and deeper commitment to the larger vision and mission. Success in space requires all of the available and assembled talents we can muster and creates a broader and diverse group of full-fledged shareholders. When those shareholders see themselves reflected in a program like Artemis, ownership takes hold with stronger, deeper and more enduring roots.

Those roots not only strengthen our reach for exploration "out there," but nourish life and create impact here on Earth where the rewards and return on investments are needed most. Today, any visit to our grocery stores or doctors' offices; or use of our computers and communications devices, was touched by Apollo.

We should never forget that the rewarding dividend of 50 years ago was cut by two competing giants. Just imagine

what a wider and more collaborative effort across countries and companies as vested partners can yield.

There is no doubt that Apollo was an unparalleled success, but that urgent sprint to the moon did not nurture the intellectual and technical roots needed to convert lunar landings into a sustainable presence. Today's more multidimensional effort—with more diverse people, providers, companies, countries and approaches—can create a real, enduring human presence beyond Earth while improving lives back on it.

We proved that with Apollo and continue to demonstrate it today on the International Space Station. In the coming years, we will showcase those benefits again when we go back to the moon while pursuing our ultimate objective – putting humans on Mars and beyond.

Neil and Buzz's small steps and giant leaps of 50 years ago certainly opened the door for humanity beyond Earth, but it is Artemis that will afford us an even more rewarding journey for generations to come. **SN**

Tom Zelibor is chief executive officer of the Space Foundation in Colorado Springs, Colorado.

Commentary | Rick Tumlinson

Why we're not on the moon now (and how we can stay next time we go)

As we celebrate the 50th anniversary of the first humans to walk on the moon, you might notice we aren't celebrating it on the moon. Why? Having achieved the greatest feat in human history, why is all we have to show for it flags, footprints and footage? 50 years after the Wright Brothers, anyone could buy a ticket to fly around the world. 50 years after Henry Ford's first Model T, regular people around the world were driving their own cars. 50 years after Apollo, we've got a few government employees orbiting around this world and no one flying to the moon, let alone any of us.

Why? Two simple reasons: Who's in charge, and their goal.

The Wright Brothers were citizen engineers who wanted to open the sky so the people could fly. And they did. Ford was a businessman who wanted to give people the freedom to travel. And he did. The U.S. government wanted to beat the Russians to the moon. And it did. It's that simple. NASA achieved its goal – but it wasn't opening the moon or the Solar System to the people, no; the goal was just to get that amazing propaganda shot on the TV for all to see. We won! We won! Look at us! We won! And...we're done.

The reason there is no one on the moon and Mars today to celebrate Neil and Buzz taking those small steps is because the goal of the Apollo program was to create a historic moment, not to change the course of history. And while it did both to some degree, imagine if, instead, the goal of that heroic effort had been to open the Solar System to the people of Earth. Who knows where we'd be today and how many of us would be somewhere out there, far from Earth?

Word is that we are going back to the moon (again). This time we have two groups leading the way – NASA and the private sector. And while both say their goal is "to stay," in actuality, they have different reasons.



Buzz Aldrin inside the Lunar Module.

NASA is going because the current administration wants to say they took us back to the moon. Thus the 2024 deadline, which happens to be the end of what might be this president's second term if he wins the upcoming 2020 election. Some NASA supporters would also like the agency to practice its Mars exploration skills on a planetary surface close to home.

The private sector is going because it wants to expand humanity into the Solar System, thereby developing new markets, and new economic opportunities. Thus, while the timeframe matters, planting a flag is not relevant. While Musk also wants to go on to Mars, Bezos and others such as myself see the moon not just as a place to practice exploration, but to learn how to harvest resources, develop industries and build communities.

Whatever the political motivations, NASA's marching orders are to get back to the moon by 2024. Meanwhile, those of us working to open the frontier permanently are driven by basic economics

and market forces to move as quickly and efficiently as possible, so returning sooner is better than later.

We can all win. To return to the moon quickly, efficiently, and in a way that both establishes a sustainable and growing human community, while supporting Solar System exploration we must first do these things:

- Agree on the end goal. This cannot be a sprint to plant the flag in the name of one administration. Rather it must be a long-term, economically viable plan to lay the foundation for the development and settlement of space by the people.

- Break up the work based on who does what best. NASA and its partners should support advanced research and scientific exploration and leave industrial work to the private sector.

- Put the money where it supports the goal. If we are to move quickly yet sustainably, NASA will have to stop wasting billions in taxpayer funds on archaic one-shot rockets and focus even more of its budget toward the proven programs that support small businesses and economic growth. The role of the government in transportation should be as it is in other sectors – to invest in and support the companies who are also investing their own money and expertise into reuseable, efficient, long-term, mass transportation and industrial development.

I was a child when we went to the moon the first time. I want my child to have the chance to go there herself. In fact, I want her and the children of Earth to be able to live there or anyplace else in the Solar System she chooses. This is a far better legacy than giving her a memory of what we once did but can't do anymore. It's time to return to the moon, and this time, We Stay. **SN**

Rick Tumlinson is the co-founder of the Space Frontier Foundation, Deep Space Industries and Orbital Outfitters, and founder of the EarthLight Foundation and New Worlds Institute.

Commentary | Robert Zubrin

Making the moon and Mars possible



In July 20, 1989, the 20th anniversary of the Apollo 11 moon landing, President George H.W. Bush got up on the steps of the National Air and Space Museum flanked by Neil Armstrong, Buzz Aldrin, and Michael Collins and declared that in the tradition of their great feat, he was declaring that the United States would now set its sights on returning to the moon by the end of the decade, this time to stay, and then push on to Mars.

The project went nowhere. NASA at that time was interested in selling Space Station Freedom as its next major project, so in its 90 Day Report to the president laying out its plan to allegedly accomplish his goal, it proposed to send crews to the moon using massive spaceships assembled on-orbit at a vastly expanded space station. The plan was so costly and complex that many veterans of the Apollo program who still filled NASA's ranks at that time could only scratch their heads their heads and wonder, "If we could put a man on the moon, why can't we put a man on the moon?"

With the return to the moon made impossible by the requirement to expand and then use the space station for on-orbit assembly, the even more convoluted Mars mission design was out of the question. Left with no prospects for attaining meaningful goals within a reasonable schedule and budget, Bush's Space Exploration Initiative died of congressional sticker shock.

History is now repeating itself. President Trump has declared he wants to send astronauts to the moon by 2024 and then Mars by 2033. But NASA wants to build a lunar orbiting space station, which it ironically calls the "Gateway." It claims that this facility is a necessity to enable lunar missions. In fact, however, NASA's plans for the Gateway were laid down before Trump's lunar initiative, by administrator Bolden, who openly declared that Americans should never return



U.S. President George H.W. Bush marked the 20th anniversary of the Apollo vision by announcing his Space Exploration Initiative during a July 20, 1989, speech on the steps of the National Air and Space Museum in Washington.

to the moon.

In other words, NASA is saying to Trump the same thing it said to Bush: "You can't do your program until you do my program."

Of course, there are excuses. The 26-ton Orion capsule is so heavy that even the long overdue Space Launch System (SLS) heavy lift booster cannot deliver it to low lunar orbit with enough propellant to fly home. So a halfway house is needed that Orion can fly to – thus the Gateway. This is the real reason why the Gateway was invented – to give Orion a place to fly to after NASA's previous fancy that it could drag a fragment of an asteroid into lunar orbit to provide a plausible rationale for Orion flights was found to be impossible.

But the SpaceX Dragon, which, unlike Orion, has actually flown, only weighs 10 tons. So SLS could readily deliver it to low lunar orbit, as could the already operational

Falcon Heavy, which costs about 1/10th as much as an SLS. In either case the Gateway could be eliminated, thereby freeing up the funds to build a lunar lander (which really is necessary if you want to land on the moon.)

So rather than enabling the goal of reaching the moon by 2024, the Gateway project is actually disabling it.

Furthermore, if we develop facilities on the surface, rather than in orbit, we can make use of hydrogen/oxygen propellant derived from lunar ice to implement a much more efficient moon base operation, which would not only allow far more extensive lunar exploration, but free up our heavy lift capability to take on new challenges further out in space.

This brings us to the subject of human missions to Mars.

As noted, administrator Bolden was an opponent of human missions to the moon, >

U.S. President George H.W. Bush (second from left) with Vice President Dan Quayle (left) and astronauts Neil Armstrong, Buzz Aldrin and Michael Collins at the Smithsonian's National Air and Space Museum in Washington on the 20th anniversary of the Apollo 11 mission.



so he could not justify the Gateway with that rationalization. Instead, he argued (as he had previously done on the equally-nonsensical asteroid redirect mission,) that it was necessary to enable human missions to Mars. Acting consistently with this conceit, NASA created a putative design for a human Mars mission that would utilize the Gateway to support the operations of an interplanetary spaceship it called the Deep Space Transport (DST). This system would use immense solar electric propulsion (EP) ion drive system to travel from the Gateway to Mars and back, with one-way trip times of 300 days. This contrasts poorly with what chemical rockets can already do, as demonstrated by the Spirit, Opportunity and Insight missions, which reached Mars in 180 days starting from low Earth orbit (LEO). If it had to start from LEO, the Deep Space Transport would take 600 days to reach Mars. The Gateway was therefore justified by baselining the wrong propulsion technology, which while bad using the Gateway, would be even more catastrophic without it.)

Furthermore, if a spacecraft were at the Gateway, it could get to Mars using chemical propulsion using less propellant than EP, despite EP's much-touted higher exhaust velocity, because the trajectories the two systems would take are different, with amount of pushing an electric propulsion spacecraft needs to reach Mars from the Gateway being 10 times that required by a chemical rocket (a velocity change of 7 km/s vs 0.7 km/s.) But in addition the EP spaceship needs to carry a huge 500 kilowatt electrical power system to drive its engines, while the chemical rocket propelled vessel only needs 10 kilowatts for life support. So if it ever actually implemented the futuristic DST, NASA would create a system which would get astronauts to Mars in twice the time, with twice the hardware mass, twice the propellant mass, a much higher development cost, and a much more complex mission plan than could be achieved using currently available off-the-shelf chemical rockets.

As if that weren't enough, the DST uses

xenon propellant, which is not obtainable from the moon, as opposed to the oxygen/hydrogen propellant used by a chemical rocket which conceivably could be. So the choice of using the unnecessary, slow, costly, complex and mission-bloating DST for Mars missions completely negates any hope that the lunar base could ever play a useful role in support the human exploration of the Red Planet.

But NASA needs the DST to justify to Gateway, because the Gateway is necessary to enable the DST. It may be nuts, but that's their story and they're sticking with it.

There is a clear alternative to such log-rolling, which is the Mars Direct plan, or plans like it, which use the upper stage of a heavy lift rocket – such as Falcon Heavy, Starship or SLS – throw necessary payloads on direct trajectories to Mars, with return methane/oxygen propellant produced in advance of the crew's arrival from Martian water and CO₂.

We don't need fantastical science fiction spaceships based at a lunar orbiting space station to enable human Mars exploration. What we do need is a heavy lander, with a payload capacity in the 20 ton range. With a proper upper stage, SLS could throw around 40 tons on trans-Mars injection, as could SpaceX's planned Starship system. This is enough to deliver a 20-ton payload capacity lander to Mars. The human Mars exploration program could then begin by exercising such a system to deliver platoons of rovers, armed with diverse instruments and tools to thoroughly explore regions of interest, demonstrate in-situ resource utilization systems, and ultimately prepare a base. The rover platoon could also photograph their region in high definition, allowing

the creation of a virtual reality simulacrum to allow thousands of people on Earth to explore alongside the rovers, ("Hey rover, this rock looks interesting. I think it could be a fossil. Come here and brush off the dust so we can have a better look.") testing out methods of Earth-Mars combined operations in advance of their use in support of astronauts. Such missions would produce an immense scientific return, while taking down the key tall pole blocking the way to human Mars exploration.

Engineering is the art of making the impossible possible. Bureaucracy is the art of making the possible impossible. By choosing bureaucracy over engineering, NASA's planners are defeating the goal of reaching the moon in five years and transforming human Mars exploration from a mission into a vision.

The question is fundamentally this; Will NASA have a purpose-driven plan or a vendor-driven plan? A purpose-driven plan spends money to do things. A vendor-driven plan does things in order to spend money. If we allow NASA's human spaceflight program to remain in its vendor-driven mode, not only will we not reach Mars by 2033, it is questionable we will even return to the moon by that time. But if we insist that our space program be purpose-driven, we can reach the moon by 2024 and Mars before the end of the decade.

Such is the choice before us. **SN**

Robert Zubrin, an aerospace engineer, is the founder of the Mars Society and the president of Pioneer Astronautics. His latest book, "The Case for Space: How the Revolution in Spaceflight Opens Up a Future of Limitless Possibility," was recently published by Prometheus Books.

Commentary | Rand Simberg

Time to go back to the moon, to truly stay



More than a year before John F. Kennedy's landmark moon speech at Rice University, the 35th president stood before the U.S. Congress on May 25, 1961, and set an end-of-the-decade goal for landing a man on the moon. Credit:

In responding to the president's desire to return Americans to the moon within his planned term of office, NASA Administrator Jim Bridenstine faces several challenges, perhaps insurmountable ones. Ignoring the political and budgetary constraints under which he must plan such a technical accomplishment, he is hampered by tired thinking going back to Apollo.

Fifty-eight years ago, almost to the day, President Kennedy declared what was, at the time, a bold national goal: To send a man to the moon within a decade, and "return him safely to Earth." The greatest challenge of Apollo was not the former, but the latter.

Simply getting someone to the moon was relatively easy, even then: Launch a rocket with a crew and a lander, and land the latter

on the lunar surface. It could be done with a much smaller rocket than the Saturn V.

But in order to return, another vehicle would be required to first get back into orbit, and then additional propellant to get it all the way back to Earth, and that vehicle would have to be capable of entry into the atmosphere and recovery on the planet's surface. As it turned out, two more vehicles were deployed: A lunar ascent stage, and a capsule for recovery into the atmosphere. Because we had too little experience with space assembly, all this additional hardware, and the propellant needed to get it all the way there and back, had to be launched in a single flight from Florida. The capsule with its precious human cargo that sat on top of the huge Saturn V launcher, is all that came back from the moon.

While Kennedy's goal was achieved, the science we got from the six lunar missions was limited by the necessarily short mission durations on the lunar surface. In particular, we continue to have no data on the long-term effects of partial gravity, including the ability to conceive and gestate healthy offspring of even rodents, let alone primates, including humans, knowledge critical to understanding the ability of humanity to thrive on the moon.

In the planning of the return to the moon, we seem to be attempting to simply repeat Apollo: Send a man (and woman) to the moon, and return them safely to Earth. But suppose we eliminate the latter requirement, at least initially?

If we don't need to bring them back immediately, the 2024 mission gets much >

For decades, with each failed programmatic attempt at a lunar return, the ostensible goal has been to “return to the moon, this time to stay.” Yet somehow, rather than being bold, the plans always start with a repeat of what we did in the 1960s.

< > simpler, and affordable: Build a habitat capable of being resupplied, and land it on the moon. Then, after verifying that it’s functional, send its first crew. We know how to build space habitats from ISS experience, and lunar habitats are easier, because they have some gravity to work with. All the necessary major hardware that would be new is a lander. A few weeks in Washington, Jeff Bezos, richest man in the world and founder of the space company Blue Origin, unveiled a mock-up of one they plan to build. There is no reason to think that, given adequate funding (and it would surely be much less than one developed by NASA under a traditional cost-plus contract), it couldn’t be ready and tested in four years (and would be required even with a planned return, though the requirements might be different).

With no immediate need for lunar ascent, the mission could be done with existing launchers, such as the Falcon Heavy.

When would the crew return? Whenever we have developed the means for them to do so, an activity that could be done in parallel, but without the 2024 urgency.

In the meantime, over months, or perhaps a year or three, they will be able to engage in long-term exploration of the moon and research into the effects of partial gravity, perhaps taking some rats along to attempt breeding.

If they had the capability to do EVA (something necessary for proper exploration in any event), resupplying them indefinitely would be straightforward, with occasional deliveries of food, water, clothing, and lithium hydroxide to scrub the habitat atmosphere, just as we do with the CRS deliveries to ISS. It would be the very definition of “sustainable.”

In fact, the marginal cost of such a mission might be sufficiently low as to allow multiple habitats and crews in different locations,



A Saturn V rocket carrying Neil Armstrong, Buzz Aldrin and Michael Collins lifts off July 16, 1969.

with regular crew rotations once a round-trip system has been developed over the next couple of years. And each base could grow as well with the delivery of additional habitats, allowing volume for experiments in lunar agriculture and perhaps aquaculture.

Is the plan risky? Of course it is. If there was a medical, or other emergency, there would be no immediate way to evacuate the crew. But for decades, we have accepted this risk at Amundsen/Scott Station, with no ability to evacuate researchers through the austral winter.

No frontier is opened without risk, and the space frontier is the harshest one humanity has ever faced. But with the acceptance of risk can come great reward, and the reward here is serious lunar research, within half a decade, far beyond the limited expeditions of half a century ago. Does anyone doubt that there are researchers, within or outside of the

NASA astronaut office, willing to accept that risk? If so, perhaps we haven’t been doing a good job of selecting astronauts, but I don’t believe that is the case.

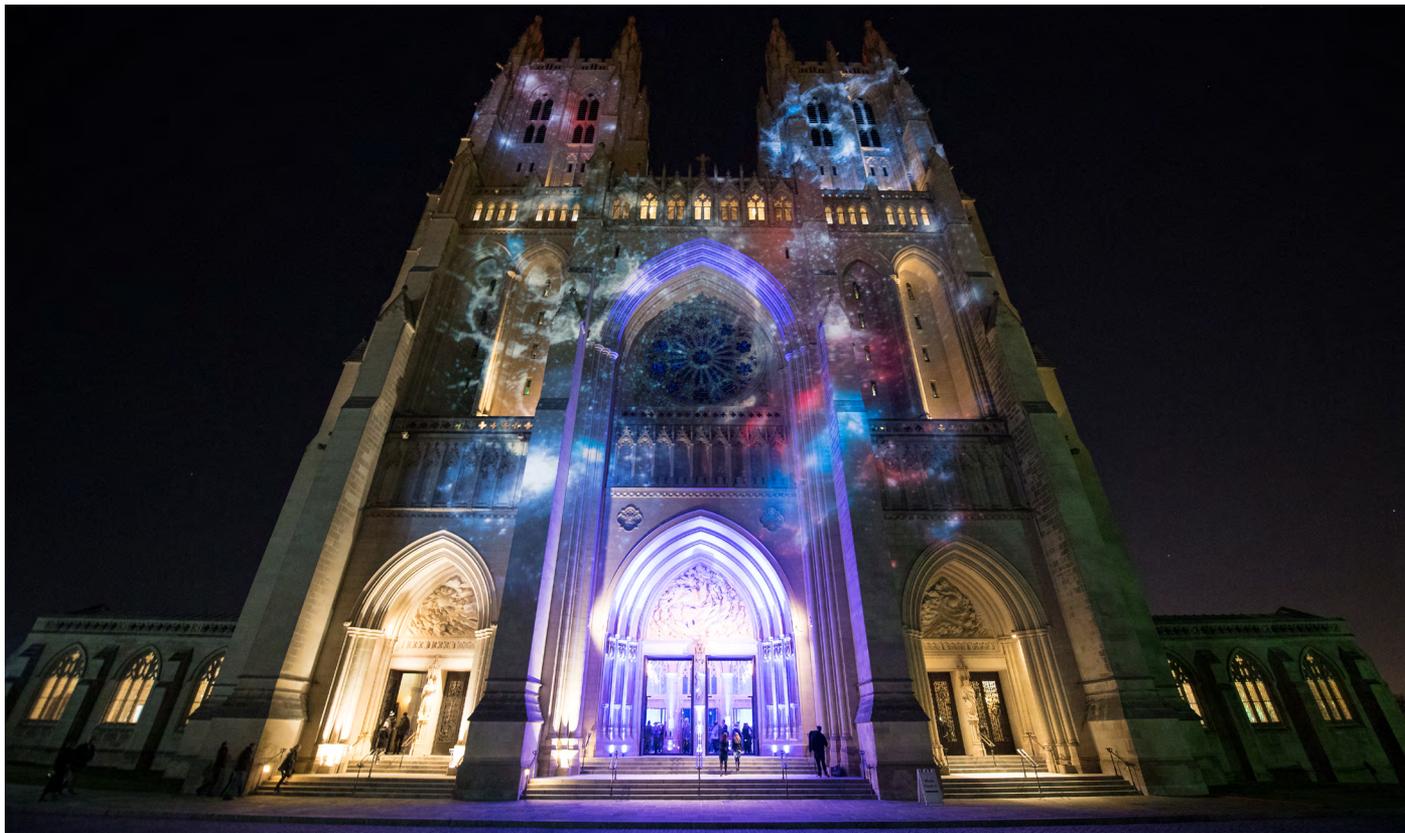
For decades, with each failed programmatic attempt at a lunar return, from President George H. W. Bush’s Space Exploration Initiative, to his son’s Vision for Space Exploration, the ostensible goal has been to “return to the moon, this time to stay.” Yet somehow, rather than being bold, the plans always start with a repeat of what we did in the 1960s.

It is now the 21st century. The best way to assure that when we go “back to the moon, this time to stay,” is to stay. Let us get on with it. **SN**

Rand Simberg is the author of “Safe Is Not an Option: Overcoming the Futile Obsession with ‘Getting Everyone Back Alive’ That Is Killing Our Expansion into Space.”

Commentary | Dick Richardson

Apollo is a lesson in leadership that continues to inspire and educate



The Washington National Cathedral is seen lit up with space imagery prior to the Smithsonian National Air and Space Museum's Spirit of Apollo event commemorating the 50th anniversary of Apollo 8 on Dec. 11, 2018.

July 20, 2019 marks the 50th anniversary of one of mankind's greatest achievements, the moon landing by Apollo 11, and the leadership it took to make that feat possible.

The story of the Apollo program, the many heroes in the headlines and those behind-the-scenes, the unprecedented crisis and tragedies that were overcome to fulfill a martyred President's bold promise, is a story as compelling as any great novel or Greek myth.

We learn through storytelling. For the past six years, the saga of the people and challenges behind Apollo have been the cornerstone of an immersive leadership seminar created by my company, and now a new book. Our workshops have taken senior managers from over 100 Fortune 500 companies to Johnson Space Center and Space Center Houston to

learn how to inspire, lead and recalibrate in times of crisis, all by modeling the work of the remarkable people behind Apollo's success.

The Apollo story dawns with the first of its many leader/heroes, John F Kennedy, a President who announced an audacious plan to reach the moon within 10 years. His 1962 speech at Rice University which laid out the vision is the model of brevity, simplicity, ethos and power. It serves as the template for today's popular TED talks.

When the story opens, America is the decided underdog. We are beat into space by the Soviet's Sputnik satellite. Then we're outpaced again when they launch the first living thing, the dog Laika, and yet again when Yuri Gagarin becomes the first man to orbit the Earth. In these early days, America does seem to be leader in one thing – producing

live television footage of rockets exploding shortly after takeoff!

In short order, America would have its successes and heroes, like the charismatic, Midwestern family man/astronaut John Glenn and the deeply intriguing and ever adaptable Wernher von Braun.

Von Braun proved a far-seeing model of leadership in many ways. First, it was by reading the tea leaves as WWII wound down to secure safe passage for himself and 100 of his fellow German scientists to America. That group would form the nucleus of the Huntsville team in righting America's ailing rocket propulsion program. Von Braun was also a fascinating example of the media-savvy leader. He used the press to reposition himself from enemy combatant to proponent of peaceful space exploration and then to >

<> the ubiquitously publicized technical guru behind NASA's Mercury, Gemini and Apollo programs. Von Braun can serve as an example for today's tech leaders through his T-shaped Management style. He was deep in his technical field (the stem of the T), but also broad in his thinking across many fields. He could scan the environment beyond his technical expertise to understand the political, societal and economic trends. This ensured his success by anticipating alternative pathways when problems arose.

Apollo also serves as a model leadership lesson in handling Tame versus Wicked Problems, a phrase coined shortly after the moon landing in 1973 by Rittel and Webber.

With Tame Problems, you can draw upon past experiences to help find solutions. You've seen the problem (or something like it) before, so you know what to do. Wicked Problems are unprecedented. Often involving many levels and factors hence unfaced. Challenges like the Deep Water Horizon oil spill or climate change are examples.

NASA faced a series of wicked problems. One of the first was the devastatingly fire that took the lives of the three Apollo 1 astronauts. Here, our seminar attendees encounter another model leader/hero, George Low. Low took a demotion to champion the redesign the Apollo capsule. But, he did more than fix the cause of the fire. He instituted over 400 improvements in the capsule design, only 40 of which dealt with the fire. Great leaders are often masters at adapting and reframing. Because of the Apollo 1 fire, the whole space program was two years behind schedule. Low ensured the continuance and ultimate success of the then heavily questioned Apollo program by adapting the missions to accommodate the delayed Lunar Lander. He got America "first to the moon" with the non-landing Apollo 8 on Christmas 1968.

Perhaps Apollo's greatest example of "wicked leadership" that pulled success out of failure came with Apollo 13. The remarkable calm of Glynn Lunney and teamwork-driven ingenuity of Gene Kranz saved the day, and the crew. That story also launched both a best-selling book and award-winning movie.

From the leadership standpoint, Apollo is also noteworthy as an example of integration. First off, it was a model of collaboration between the public and private sectors, a mission that would've been nowhere without the work of Grumman, Northrup, Boeing, etc., as well as a host of government, military nonprofit and university institutions.

NASA was also one of the first large organizations that brought opportunities to



The so-called "space window" at the National Cathedral in Washington includes a 7-gram piece of the moon that Apollo 11 astronauts Neil Armstrong, Buzz Aldrin, and Michael Collins delivered to the cathedral during a July 21, 1974 ceremony.

people who maybe hadn't enjoyed them before. This included foreigners like Von Braun and his team and minorities, such as the four African-American women mathematicians chronicled in the book and film, *Hidden Figures*. Like today's tech giants, NASA also valued and placed huge responsibility in the hands of young talent, as evidenced by 24 being the average age of the Mission Control team during the Apollo 11 moon landing. This integration was an example of the best in America, welcoming talent from all over the world, from every corner of society, to achieve greatness.

One of the most important model leaders in the Apollo story is Jim Webb. Webb was a finance expert. He doubted his own ability to lead NASA and tried to turn down the job of Chief Administrator, due to his lack of hard technical knowledge. But, when he had no choice but to accept LBJ's dictum, the ego-free Webb compensated for his own perceived knowledge gap by creating "The Triad," a three-person governing body. The Triad team included himself, his more tech-savvy predecessor Hugh Dryden and, for large scale organizational expertise, former RCA COO Robert Seamans. These three men ran all of NASA's major decisions by consensus and collaboration for seven years. They put America on the moon. A good business leader

also works to squeeze extra value out of every dollar invested. Webb did this by insisting the private companies he provided large contracts to support American education. He required that they hire research departments at institutions like MIT and Purdue. These grants and contracts served to fund the infrastructure of educational institutions across the country.

For 30 years, I have devoted my life to teaching senior executives lessons of leadership, first at companies like IBM and ITT, then at The Conference Board and, for six years, as founder of Experience to Lead. Our company offers unique, immersive experiences that take senior business executives to sites, like the battlefields of Gettysburg and Normandy and the U.S. Airways' "Miracle of the Hudson" plane, on which I was a passenger, to absorb lessons designed to improve their leadership skills.

Our Apollo Leadership Program came about by serendipity, when we were looking to expand beyond our Gettysburg and Normandy programs with another compelling story of leadership.

When we approached NASA with the idea, they directed us to one of their own, Matthew Gray, who, by chance, had attended one of our Gettysburg workshops. Gray became instrumental in supporting us as we developed the program, which lasts three days and takes attendees to the Johnson Space Center and Space Center Houston, the adjacent museum that both preserves important artifacts and encourages the study of science and math by children.

As NASA is a federal agency prohibited by ethical code from promoting itself in such as way, our program has served to highlight the great successes of Apollo, to some of the business world's most influential movers and shakers, ones who can help return our national focus to space exploration.

Even after three days in workshops absorbing this story, business leaders asked for more, hence our decision to put the story, and more, into book form. My book, "Apollo Leadership Lessons: Powerful Business Insights for Executives," is just what is advertised – a look at how leaders, on all levels and in many corners of NASA, helped mankind reach what still stands, 50 years on, as our greatest technological and collaborative achievement. **SN**

Dick Richardson is the founder and CEO of Experience to Lead and author of *Apollo Leadership Lessons* (Authority Publishing).

Commentary | Gary Oleson

The Apollo program and the Chinese treasure fleets



The Apollo program and the voyages of the Chinese treasure fleets funded by the Ming dynasty's Yongle Emperor had much in common. Both programs were ostensibly programs of exploration. Both programs ventured far beyond the prior range of their sponsors, and both programs were fabulously expensive.



History tells us that if our new commercial space industries succeed and grow,

there will be no end to our space expansion. Supporting economic development of space is, therefore, the most important thing the United States can do right now to assure the future of its human spaceflight programs and humanity's future in space.

During the decades since the cancellation of the Apollo program, some have used the Chinese treasure fleets of the early 1400s as a cautionary tale. Great Chinese fleets crossed the Indian Ocean more than 60 years before the Europeans got there, but then they ended their program and cleared the way for Europeans to dominate the world. The argument is that the United States' failure to continue Apollo-style space exploration could lead to some other nation dominating humanity's future. A

closer examination of the comparison suggests a different outcome.

BUYING PRESTIGE

Early in his reign, the Yongle Emperor of China's Ming dynasty wanted to expand Chinese influence in the world. He appointed Admiral Zheng He in 1405 to lead a huge treasure fleet on an expedition through the East China Sea and across the Indian Ocean. They reached the western coast of the Indian peninsula and returned in 1407, bringing gifts and emissaries from many countries. While Chinese traders in small ships had ventured as far as the Persian Gulf, the treasure fleets were the first large-scale, official expeditions to cross the Indian Ocean.

The Ming treasure fleets made a total of seven voyages between 1405 and 1433 to establish the superiority of Chinese culture, wealth, technology, and military

power over a broad swath of Southeast Asia and around the Indian Ocean. The Ming voyages eventually ventured beyond India, reaching the Persian Gulf, the Red Sea, and the east coast of Africa. Accounts credit the first voyage as having more than 250 ships with nearly 28,000 crew members. The largest of the vessels were among the largest wooden ships ever built.

The Ming fleets were called treasure fleets not because they brought treasure back, but because they were lavishly expensive and took treasure with them to inspire awe and give to the rulers of the countries they visited. They returned with ambassadors and tribute, although the tribute was more symbolic than practical and did not counterbalance their vast expenditure. For example, giraffes were specially prized because they resembled a propitious creature from Chinese mythology.

The treasure fleets were supported by >

The lesson to be learned from the shared fate of the Chinese treasure fleets and the Apollo program is that expensive programs supported only by a political mandate are not sustainable.

< > the expansionist eunuch faction of the Ming court and opposed by conservative Confucian scholar-bureaucrats. When the Confucian faction gained ascendancy, they ended the voyages, banned construction of large oceangoing ships, and eventually scrapped the remaining vessels.

The Ming voyages were followed two generations later by European voyages of exploration and trade that proved more sustainable. While government investment in technology and military power supported both maritime programs, the European enterprises were organized as public-private partnerships. They focused more on establishing persistent trading relationships based on a profitable return on investment.

The Europeans reached India and its spices in 1498, while establishing profitable trade all along the route. They then continued to China. Unlike the Chinese, they built a string of trading posts, forts, and factories that supported a permanent presence. The effects of that presence continue to this day.

Five-and-a-half centuries after the Chinese treasure fleets, U.S. President John F. Kennedy used NASA's Apollo program as a response to a string of Soviet space accomplishments that included launching the first artificial satellite and putting the first man in orbit. Surpassing the Soviet Union in space became an American political imperative. At the peak of the Apollo program, NASA commanded 4 percent of the federal budget and 1 percent of the entire U.S. economy.

While the goal of the Apollo program was a manned moon landing, its central purpose was to establish American technological superiority and national prestige. The United States took the lead when the Apollo 8 mission orbited the moon in December 1968. The purpose of the Apollo program was accomplished when the Apollo 11 mission captivated the world by



A full-size replica of a medium-sized treasure boat of the Adm. Zheng He fleet at the Treasure Boat Shipyard site in Nanjing, China.

landing on the moon in July 1969.

NASA's budget was declining even before the moon landing, and the agency's popularity began dropping immediately afterward. The decline was accelerated by President Richard Nixon, who was not fond of Kennedy's program. NASA's budget dropped quickly to 1 percent of the federal budget and has since drifted downward to its current half percent. The last three Apollo missions were canceled after the giant Saturn V boosters for them had already been built. One booster was repurposed to launch the Skylab orbital workshop, and the other two were put on display as museum exhibits, a step up from scrapping them.

The Apollo program and the voyages of the Chinese treasure fleets had much in common. Both programs were ostensibly programs of exploration. Both programs ventured far beyond the prior range of their sponsors, and both programs were fabulously expensive.

The most important similarity between the voyages, however, was in their purpose. They were both organized in response to a political mandate to establish

the dominance of their cultures. In each case, the political mandate was satisfied quickly. And in each case, the combination of great expense, a satisfied mandate, and a change in government ended the program without a comparable successor. Neither program survived outside the unique political conditions that created them.

The lesson to be learned from the shared fate of the Chinese treasure fleets and the Apollo program is that expensive programs supported only by a political mandate are not sustainable. Any government exploration program viewed as expensive and not resulting in production of new wealth will always be one adverse political turn away from termination.

The European (and later American) strategy of exploration and economic development via public-private partnerships has proven far more sustainable over the last six centuries. Producing a positive return on investment each step of the way guaranteed not only continuance, but expansion. **SN**

Gary Oleson is a senior engineer at SAIC and a member of the board of directors of the Space Frontier Foundation..

Commentary | Harry Augensen

Reflections on the U.S. space program a half-century after Apollo 11

As the Apollo 11 Landing Module carrying Neil Armstrong and Buzz Aldrin descended to the lunar surface, I was a college-bound 18-year old following the entire spectacle on television at my best friend's house located on a farm in northern Illinois. It was the afternoon of July 20, 1969. Much later that evening, just before midnight Central Daylight Time, I was back home with my family watching on our black and white television as Neil Armstrong stepped out of the lunar lander and climbed down onto the moon's surface for the first time. Indeed, we were witnessing "one small step for man, one giant leap for mankind." Nevertheless, my maternal grandmother who lived with us and was born in Eastern Europe in 1890, exclaimed, "I don't believe it and will never believe it."

To put things into perspective, H.G. Wells published his novel "The First Men in the Moon" in 1901, two years before the Wright brothers flew their first experimental airplane at Kitty Hawk. The notion of machines flying even short distances through the air, let alone through space and reaching the lunar surface, was considered pure fantasy. Yet, the Apollo 11 astronauts landed on the moon less than seven decades later. Surely a number of college-bound 18 year-olds at the turn of the 20th century would have lived long enough to watch in awe as Neil Armstrong descended to the lunar surface in 1969.

Inspiration and Education. During that summer of 1969, I worked in the shipping department of a factory that produced springs primarily for the automotive industry. In the evening I usually came home dingy as a coal miner, my clothes often stained with industrial chemicals and my lungs full of factory smoke and dust, the unavoidable consequence of working in that type of job. But I needed to earn the



Command Module pilot Michael Collins practices in the CM simulator on June 19, 1969, at Kennedy Space Center.

extra money for help with college expenses. Although early the next morning, I was back in the factory packing springs and other automobile parts to be installed in Earth vehicles, the historical achievement that I had just witnessed inspired me (and doubtless countless other teenagers) to become scientists.

I had already determined to pursue a career in astronomy by this time, and was preparing for college, to major in both physics and mathematics. Eventually I would obtain a Ph.D. in astronomy and pursue a career as a college professor. My best friend was also destined to obtain a Ph.D., in his case in chemistry, followed by a career in research on polymers for the U.S. government. While neither of us needed to be convinced of the significance of this achievement, it nevertheless was inspirational for two young people starting to embark on their career paths in science.

The Space Race Begins. I was just starting elementary school when the space race was getting up and running in the late 1950s. In October 1957 the world was shocked when the Russians announced that Sputnik had achieved orbit about the Earth. My teacher told our class that we could see "this thing" in the sky at night if we knew where to look for it. I recall my parents telling me one morning that they saw it one evening after I had gone to bed. It should be emphasized to today's generation that no one had done anything like this before, and many children and even a few adults (including my grandmother) were afraid of what the Russian satellite might be capable of doing to us.

In the mid-1950s, President Dwight Eisenhower had already planned to have the U.S. launch a satellite using a Vanguard rocket during the International Geophysical Year (1957-1958), not seriously considering that the Soviets might have similar plans. >

The Apollo 11 Command/Service Module is shown being readied for moving to the Vehicle Assembly Building for mating to the Saturn V rocket in preparation for its July 16, 1969 launch.

< > When the news of Sputnik 1's successful launch was announced, the reaction from our political leaders was one of deep concern that the Soviets had taken the early lead in the space race. To be sure, we were not going to allow them to hold on to it. In November 1958, a little over a year after Sputnik and at the president's direction, NASA was founded to begin the American venture into space. The Mercury program was established that same year, and in 1961 Alan Shepard became the first American astronaut to go into space. John Glenn became the first American to orbit the Earth a year later in 1962, but Yuri Gagarin had already circled the Earth for the Soviets in April 1961. It was clear that the U.S. was falling behind in the space race.

We Choose to Go To the moon. In May 1961, President John F. Kennedy gave a speech to the nation stating that the U.S. should have as its goal sending a man to the moon and returning him safely to Earth, to be achieved by the end of the decade. The public was not yet convinced that JFK's proposed initiative was worth the cost, and so in September 1962 he gave a second speech at Rice University in Houston to argue forcefully for this bold venture. Initially, Kennedy was not certain that the high price tag of such a monumental project would be worth the effort, but the great strides being made by the Soviets soon convinced him that inaction would mean second place in space.

To ensure that young school children like myself were kept informed of the historic effort that our nation was undertaking, black and white TVs with typical American brand names such as Zenith or Admiral and topped with rabbit-ear antennas were wheeled into our classrooms. My classmates and I were able to watch in real time the various mission launches from Cape Canaveral in Florida.

What Was Known About the Moon Prior to 1957. Prior to the space age, the best resolution that the largest Earth-based telescopes could achieve was only about one-half mile, so that even objects the size of a football



stadium would be too small to see. Surface temperatures were measured using infrared detectors, and crude chemical compositions were deduced using spectroscopy. The field of lunar geology was still in its infancy, and lunar chemistry and lunar physics did not yet exist. But that was all about to change.

The Russians Strike (Literally) First. The Russians (the former Soviet Union, or U.S.S.R.) were first to send unmanned spacecraft to the moon. Luna 2 was first, crashing on the lunar surface in 1959, while that same year Luna 3 returned photos from the moon's far side. In 1966, Luna 9 landed on the lunar surface and transmitted pictures. But the U.S. was not to be outdone. In that same year 1966, the U.S. launched five Lunar Orbiters which mapped entire lunar surface in detail. A total of five Lunar Surveyors landed, conducted experiments and took detailed pictures. The information gained paved the way for the first Apollo landing three years later.

The Apollo Program. The Apollo program is responsible for most of what we know about the Moon today. It consisted of nine manned spacecraft that traveled to the Moon between 1968 and 1972. A total of 12 astronauts reached the lunar surface over six landings. The first three landings were on flat plains (geologically safe), while for the last three landings more geologically challenging sites were selected. In fact, a geologist, Harrison Schmidt, was among the crew for the final Apollo landing. The Apollo

missions accomplished the most important objective of collecting nearly one-half ton of rock samples to return to Earth for analysis; these samples allowed scientists to understand the Moon and its history. In addition, detailed photographic analyses of the lunar surface were conducted from orbit. The Apollo 11 mission conveyed an excitement that we had taken "one giant leap" forward in our exploration of the universe. It was a watershed moment, demonstrating conclusively that humans could leave Earth, travel to other bodies in space, and return to Earth.

Apollo Ends. The last human walked on the surface of the moon in December 1972 during the Apollo 17 mission, over three years after the Apollo 11 landing. In July 1975, an Apollo Command/Service Module docked with a Soviet Soyuz capsule, with astronaut and cosmonaut greeting each other with a historic handshake as a symbol of friendship between the two rival superpowers. Shortly thereafter, however, funding for Apollo was cut off due to rising economic pressures, and loss of interest by the public. Eventually, the giant Apollo rockets were put on display on the lawns of NASA in Florida and Texas for the public to appreciate the historical significance of the Apollo program. The cost of the entire Apollo program was about \$25 billion (over \$100 billion in today's economy).

Mariners to the Planets. Not getting nearly the same level of publicity while running essentially concurrently with the Apollo Program (and costing much less) was the >

< > Mariner Program, which was conducted jointly by NASA and the Jet Propulsion Laboratory (JPL) in Pasadena. From 1962 to 1973, a series of robotic interplanetary probes were launched to investigate the terrestrial planets Mercury, Venus and Mars. The Mariner program boasted the first planetary flyby (Mariner 2, Venus), the first successful Mars flyby (Mariner 4), the first U.S. planetary orbiter (Mariner 9, Mars), and the first employment of the fuel-saving gravity assist (or “slingshot”) method (Mariner 10, Venus). The total cost of the Mariner program was approximately \$550 million, a small fraction of the \$25 billion for the entire Apollo program.

Robotic Probes Continue to Deliver. Following Mariner, NASA planned and launched a plethora of successful (and a few unsuccessful) robotic probes that have expanded our knowledge of the solar system bodies. The seven of the 10 Mariner spacecraft that were successful served as the starting point for many subsequent NASA/JPL space probe programs in the 1970s, including the Voyager probes to Jupiter and the outer planets and the Viking orbiters around Mars. In the 1980s, Mariner-based spacecraft included the Magellan orbiter around Venus and the Galileo probe which gave the first close-up images of an asteroid (Gaspera) and also explored Jupiter’s atmosphere. And in the 1990s, the Cassini–Huygens Mission, which also involved the European Space Agency and the Italian Space Agency, explored Saturn from orbit and also landed a robotic probe on the surface of Saturn’s largest moon, Titan, both firsts. Most recently, in 2015, New Horizons became the first spacecraft to reach Pluto, and took amazingly detailed pictures of Pluto and its satellite Charon. New Horizons continued its outward journey and in 2019 sent back images of Ultima Thule, a bizarre trans-Neptunian object located in the distant Kuiper Belt.

Return to the moon. Over the decades since Apollo, NASA has considered returning to the moon, but with changing administrations in Washington come changing priorities. The most recent directive is to construct a Moon-orbiting space station to be completed as early as 2024. The Lunar Gateway Space

Station, as it is now designated, will be designed to provide an orbiting base around the moon from which astronauts could descend to the lunar surface, or as a starting point to go farther into space.

The Artemis Program. NASA’s successor to the Apollo Program will be the Artemis Program, a crewed spaceflight program with domestic and international partners. The goal will be to land the next humans on the lunar surface by 2024, as a first step toward a longer-term goal of establishing a sustained American presence on the moon, with the ultimate goal of sending humans to Mars. The Artemis Program will use the Orion vehicle, a planned spacecraft to take astronauts into space beyond Earth orbit, with crewed missions starting in the 2020s. Orion is similar in shape to the Apollo spacecraft, but much larger and more advanced. Orion will be designed to carry up to six astronauts to the moon or Mars. The proposed cost for the 2020 fiscal year would be around \$23 billion, but this would need to be formally approved by Congress.

Epilogue. We went to the moon for reasons relating more to the international politics of the day than to the quest for scientific knowledge. That said, the science that was learned from the Apollo landings was unparalleled, and probably wouldn’t have happened at all (at least not during the 1960s) without the urgency of beating the Russians. As with any bold endeavor, Apollo proved to be a costly one in terms of human lives, as evidenced by the tragic loss of three American astronauts in the Apollo 1 fire in 1967 (and likely many more Soviet cosmonauts who were competing with Apollo). But it also brought unintended rewards. The various compact electronic devices in use today (e.g., smartphones, laptop computers) can be traced back to the need for miniaturization of computers and electronics on board the various Apollo and later spacecraft.

Was it all worth it? Absolutely. Future historians will no doubt look back at the Apollo Program as a necessary early step in the human venture to the planets in our solar system and, ultimately, to planets orbiting distant stars. Above all, the Apollo Mission demonstrated

that humans can journey through space away from their home planet and safely land on another world. It expanded our horizons and opened the possibility of constructing a permanent or semi-permanent lunar base which could serve as a springboard for future manned flights to Mars and possibly other solar system bodies. The water ice believed to be present in craters near the moon’s north and south poles could be a significant boon to supporting a human presence on the lunar surface.

Supplement: NASA’s Budget. The NASA budget as a percent of the total U.S. spending has been relatively small compared with, for instance, defense, and moreover has been decreasing since the 1960s. During the early years of the space program 1959–69, the end of which was capped by Apollo 11, the budget varied somewhere between 2 percent and 4 percent, with an average of around 2.5 percent. This dropped during the 1980s to about 1 percent, and has been steadily decreasing since the 1990s to the current value of around 0.5 percent of the total budget of \$4.4 trillion for fiscal year 2019. The U.S. government has allocated a grand total of \$0.60 trillion for NASA over its 60 year existence. When adjusted for inflation, this translates to \$22 billion per year.

Whatever the budget constraints, an enormous amount of space science has been accomplished over the past six decades with not only robotic spacecraft, but also with orbiting satellites, both with and without crews, including Skylab, the International Space Station (ISS), the Hubble Space Telescope, and the Cosmic Background Explorer (COBE) satellite, to name just a few. Some of the more recent ventures are joint missions with other nations, and some not involving the U.S. In addition, private companies such as SpaceX are now also launching satellites for communications and scientific purposes, and it is expected that space travel will be a multibillion-dollar tourist industry for the affluent. How things have changed since Neil Armstrong first planted his foot on lunar soil half a century ago! **SN**

Harry Augensen is the director of the Widener Observatory in Chester, Pennsylvania.

Review: Chasing the Moon

Chasing the Moon: The People, the Politics, and the Promise That Launched America into the Space Age

by Robert Stone and Alan Andres

Ballantine, 2019

hardcover, 384 pp., illus.

ISBN 978-1-5247-9812-3

US\$32.00

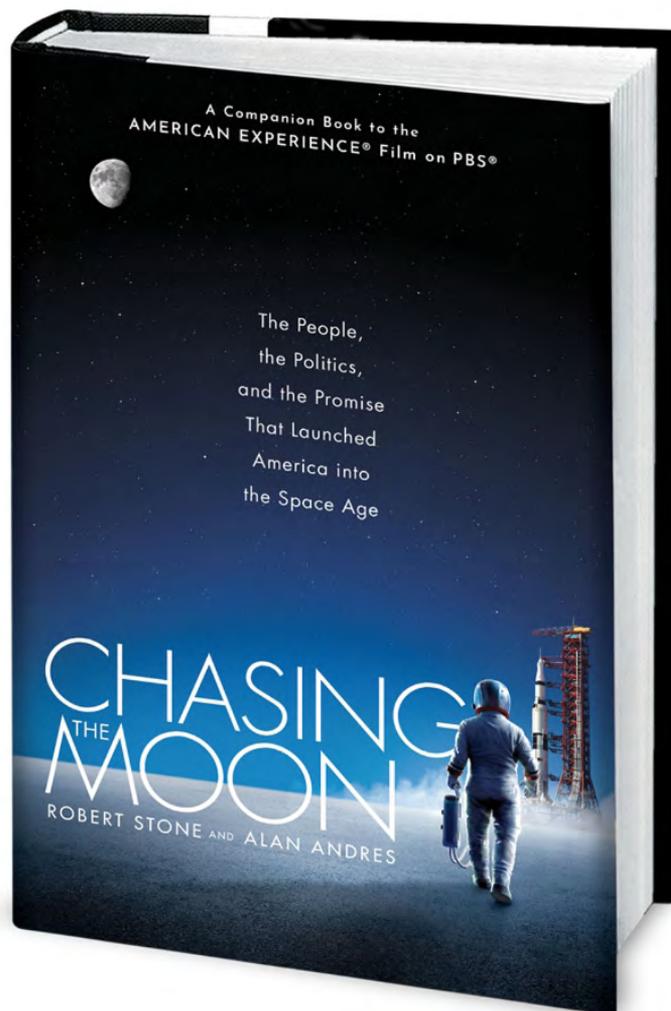
As the 50th anniversary celebrations of Apollo 11 reach their crescendo this month, television is getting into the act. A number of documentaries and other special programming is scheduled for the coming weeks, such as a version of the Apollo 11 film that appeared in theaters earlier this year that will be on CNN July 20. PBS, meanwhile, is airing a three-night, six-hour documentary, starting July 9, as part of its American Experience series called “Chasing the Moon” that examines the events that led up to Apollo 11.

Accompanying that series is a book, also called “Chasing the Moon,” by filmmaker Robert Stone and Alan Andres, who served as a consulting producer and researcher for the series. That book treads familiar ground in its overview of Apollo, but does so in a way that should be interesting to those who know much of that history already.

The book’s subtitle notes its emphasis on “the people, the politics, and the promise” of going to the moon. That is an accurate assessment of the book’s contents, which focus on personalities and policy versus science and technology. If you’re looking for a detailed technical analysis of the development of the Saturn V or the Lunar Module, or the science that the lunar landings and the samples they returned enabled, this is not the book for you.

If, though, you’re curious about the people who made Apollo possible, this is an engaging book. “Chasing the Moon” focuses some attention, as you would expect, on key individuals in the program, from Wernher von Braun and NASA administrator James Webb to the Apollo 11 astronauts. However, the book also devotes attention to some of the lesser known, more tangential figures who were either involved in Apollo or influenced it in some way: science fiction author Arthur C. Clarke, NASA public affairs head Julian Scheer, and Poppy Northcutt, the first woman to work in Mission Control during Apollo.

The book doesn’t offer much in the way of revelations about the program or the people involved, at least for those people who have read their fair share of Apollo histories. However, the book does help establish the human dimension of what has largely been described as a political and technical achievement. Clarke, for example, had his interest in spaceflight started by a book he got as a teen titled “The Conquest of Space” by David Lasser, whose career was primarily spent in organized labor and had a bid to get a government job derailed in the 1940s when a congressman described him as a “crackpot with mental delusions that we can travel to the Moon!” Scheer, who joined NASA



after working as a newspaper reporter who covered the civil rights movement, helped administrator Thomas Paine defuse a demonstration by civil rights activists outside the gates of the Kennedy Space Center the day before Apollo 11’s liftoff; he also has a second career as a children’s book author.

The book, of course, touches upon the bigger, better known issues and controversies as well, such as von Braun’s Nazi ties and the political debates about the race to the moon, including those that came after the Apollo 1 disaster in 1967. The emphasis there, as with other aspects of the book, is not the rockets and spacecraft, or the missions they flew, but rather the people who made it possible. That makes this book — and, presumably, the documentary that it supports — a useful counterpart to the other histories, including those published this year, that focused primarily on the big names and the big rockets. **SN**

JEFF FOUST

Review: One Giant Leap

One Giant Leap: The Impossible Mission That Flew Us to the Moon

by Charles Fishman
Simon & Schuster, 2019
hardcover, 480 pp., illus.
ISBN 978-1-5011-0629-3
US\$29.99

This summer is one of celebration of the 50th anniversary of the Apollo 11 landing, including the series of books about the mission and events around the country, as well as product tie-ins on everything from beer to Oreo cookies. But in the back of minds of many, though, is the realization that while we will celebrate this summer the landing of the first humans on the moon, in three and a half years we will commemorate the 50th anniversary of the landing of the last humans—to date—on the moon. Even with the acceleration of NASA's Artemis program, and private efforts, it's highly unlikely there will be any humans on the Moon before the 50th anniversary of Apollo 17 in December 2022.

The end of Apollo started decades of efforts to try to at least duplicate it, if not expand on it, and also decades of hand-wringing about the failures to do so. While Apollo might have been a success in a Cold War-fueled race, it was a failure to expand humanity's presence into the solar system. A new book, "One Giant Leap," tries to recalibrate the definition of long-term success or Apollo, with mixed results.

If Apollo was supposed to be the start of human exploration and settlement of the solar system, author Charles Fishman acknowledged, then it was a failure. "The success is the very age we live in now," he argues early in the book. "The race to the Moon didn't usher in the Space Age; it ushered in the Digital Age." NASA's demand for integrated circuits needed for Apollo's computers supported early development of such chips, improving their quality and decreasing their cost, thus stimulating other applications for them. NASA also, he says, "changed our perception of technology's appeal and usefulness" in general.

That is an interesting argument to make, but Fishman doesn't spend much of the book fleshing it out. (It ignores, for example, the role the Air Force's Minuteman missile program played in stimulating demand for integrated circuits; as Paul Ceruzzi noted in his book "A History of Modern Computing," both programs played key roles in the rise of integrated circuits, with Minuteman coming first.) Fishman undermines his own argument just a few pages into this discussion: "Would we have had microchips and laptops without Apollo? Of course." NASA should still get credit for its role, he says, but it's clear that the technology would have developed anyway even without that early race to the moon.

A couple of chapters in the book do explore the development of the Apollo computers and software; these are among the most interesting chapters in the book. But there's no flow to much of the book: after those chapters, Fishman then goes to the "secret" tapes made by President Kennedy of his discussions about Apollo (which, of course, have not been secret for decades), the development of the



lunar module, and the process by which NASA decided to and selected a flag to fly on the lander; those last two chapters are about the same length. It's certainly not a detailed or chronological account of Apollo, but rather a hodgepodge of topics about the program.

Fishman returns to that reconsideration of Apollo in the final chapter of the book. It is a bit defensive, arguing, as he did earlier in the book, that it helped begin the "Digital Age" and wasn't a waste of money. "We love space," he said. "We are not, in fact, bored by the romance and adventure of our own space travel." Yet, as he acknowledges elsewhere in the book, public support for Apollo was never strong until Apollo 11 itself, and television audiences dropped dramatically for the landings after Apollo 11. The public's interest in space, then and now, is broad but not deep.

Rather than attempting to redefine the meaning of success for Apollo, as this book attempts to do, let's accept Apollo for what it was: a tremendous programmatic success thanks to both technological accomplishments as well as skilled management, stimulated and supported by Cold War geopolitics. Trying to redefine it makes as little sense as trying to duplicate it, as decades' worth of failed initiatives have demonstrated. If human spaceflight does have a long-term future, on the moon, Mars, or elsewhere, it will look very different from Apollo. **SN**

JEFF FOUST

Review: The Moon

The Moon: A History for the Future

by Oliver Morton

The Economist, 2019

hardcover, 352 pp., illus.

ISBN 978-1-5417-7432-2

US\$28.00

In this summer of the moon, the majority of the books being published are mostly backwards-looking, revisiting the Apollo program and the race to the Moon a half-century ago. Some do look ahead at the future of lunar exploration—by NASA, other space agencies, or the private sector—and others focus on the study of the Moon or other ancillary aspects.

It's unlikely, though, that any of this new crop of books will be as wide-ranging, and as entertaining, as "The Moon" by Oliver Morton, a staff writer at *The Economist*. The book is a collection of essays that examines all those aspects of the moon, and more, and does so in a way that will be thought-provoking even for those familiar with those topics.

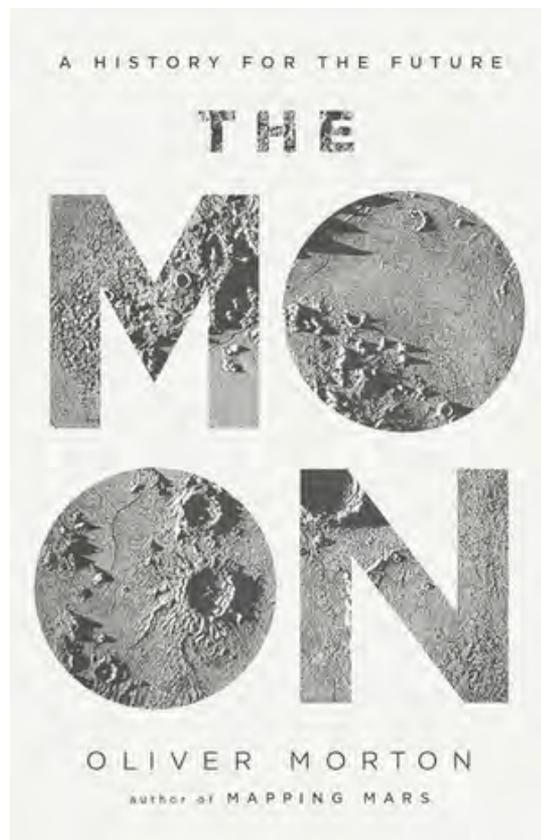
The book chapters are vaguely chronological, starting with our early understanding of the moon, then its initial exploration in Apollo, and finishing with an examination what the future might hold in terms of a human return and even settlement. But each chapter is an adventure in and of itself. The first chapter, "Reflections," starts with early 21st century observatories looking at the moon but then goes through Galileo's observations of Earthshine on the crescent moon, then to radar and radio bounces off the moon and observations of the moon recorded by the Apollo 8 astronauts, finally returning to those modern-day telescopes, which were taking spectra of the Earthshine to know what to look for as they seek inhabited exoplanets. That path might sound convoluted, but on the page it flows smoothly from one section to the next, a curious writer guiding the reader along a path that brings them back to the beginning, enlightened.

While the publication of "The Moon" coincides with the 50th anniversary of Apollo 11, very little of the book is about Apollo itself. Morton devotes just one chapter of eight to the program, and that is a high-level overview that will offer little new to readers other than his observations and perspectives on the program. If nothing else, his description of the shape of the lunar module's ascent stage ("a stubby-circular face like that of a somewhat satanic Thomas the Tank Engine") guarantees you will not look at that spacecraft the same way again.

Later chapters examine the prospects for a human return to the moon. This includes some references to NASA's plans (although the administration's announcement in March that accelerated the timetable for a human return to 2024 was too late to make it into the book), as well as what China may do. He also examines the visions of Elon Musk and Jeff Bezos, whose broader visions of humanity's future in space may support a return to the moon.

In these chapters, Morton sounds like someone who wants to

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believe humans will return to, and stay on, the moon, but who retains significant doubts. He often refers to this as "the Return," but accepts this is not as preordained as it sounds. For example, he examines the possibility of establishing a base on the moon to mine ice, transporting it back to Earth orbit where it could be sold as fuel. But, he notes, the business case for such a facility likely relies on low-cost access to space using vehicles like SpaceX's Starship; yet, those vehicles could undermine that market for lunar ice by simply transporting water from Earth.

And, while he acknowledges the advances of the private sector, he does not uncritically idolize them. Musk, he notes, "has led the most successful spacecraft development programme since Apollo," and that the company's future Starship could "mop up NASA contracts" for lunar missions should the Space Launch System go by the wayside at some point. Yet, he writes, Musk "is also a prick" that qualifies any admiration of his achievements. (Bezos gets off easier, but Morton says one "should not discount the possibility of prickishness.")

That ambivalence about our future on the moon, and the role of the moon in our future, is made clear in a passage late in the book, after an examination of the moon's place in science fiction. "There was a time when the Moon, standing for all things that rockets might reach, functioned as an image of the future; that was how science fiction used it, that was what the Apollo programme made it," he writes. "Now it seems, at best, a future among others—and a slightly retro one." Although it may be retro, it's clear the Moon is still inspirational for many, including Morton, who still believe—or at least hope—it is a part of humanity's future, in one manner or another. **SN**