Comments of

TechFreedom

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In the Matter of

Moon to Mars Objectives

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I. Background

TechFreedom files these comments in response to NASA's call for comment on its Moon to Mars Objectives (the "Objectives").[2]

Founded in 2010, TechFreedom is a non-profit think tank dedicated to promoting the progress of technology that improves the human condition. To this end, we seek to advance public policy that makes experimentation, entrepreneurship, and investment possible, and thus unleashes the ultimate resource: human ingenuity. Wherever possible, we seek to empower users to make their own choices online and elsewhere.

TechFreedom, and the undersigned author, have almost 40 years' experience in outer space law and policy. A short list of our work includes:

- Testimony before the U.S. Senate on the proper role of government in meeting its obligations under Article VI of the Outer Space Treaty (OST);[3]
- Amicus briefs in key court cases related to outer space law and policy;[4]
- Law review articles addressing key issues of space law;[5]

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[2] *See* Cheryl Warner, *Update: NASA Seeks Comments on Moon to Mars Objectives by June 3*, NASA (May 17, 2022), https://www.nasa.gov/press-release/update-nasa-seeks-comments-on-moon-to-mars-objectives-by-june-3.

[3] *Reopening the American Frontier: Exploring How the Outer Space Treaty Will Impact American Commerce and Settlement in Space: Before the Senate Committee on Commerce, Science, & Transportation Subcommittee on Space, Science, and Competitiveness*, 115th Cong. (2017) (written testimony of James E. Dunstan & Berin Szóka), https://www.commerce.senate.gov/services/files/A9AD88B2-9636-4291-A5B0-38BC0FF6DA90 (for video of the hearing, *see Reopening the American Frontier: Exploring How the Outer Space Treaty Will Impact American Commerce and Settlement in Space*, U.S. SENATE COMMITTEE ON COMMERCE, SCIENCE, & TRANSPORTATION (May 23, 2017), https://www.commerce.senate.gov/2017/5/reopening-the-american-frontier-exploring-how-the-outer-space-treaty-will-impact-american-commerce-and-settlement-in-space.).

[4] Amicus Curiae Brief of TechFreedom, Viasat v. FCC, No. 21-1123 (D.C. Cir. Sept. 28, 2021), https://techfreedom.org/wp-content/uploads/2021/09/File-Stamped-TechFreedom-Amicus-Brief-Viasat-v-FCC.pdf.

[5] *See* James E. Dunstan*, "Space Trash:" Lessons Learned (and Ignored) from Space Law and Government,* 39 J. OF SPACE L. 23 (2013); James E. Dunstan, *Toward a Unified Theory of Space Property Rights*, *in* SPACE: THE FREE-MARKET FRONTIER (2002); William J. Potts Jr. & James E. Dunstan, *Creeping CANCOM: Canadian Distribution of American Television Programming to Alaskan Cable Systems*, 7 PACE L. REV. 127 (1986); James E. Dunstan et al., *The Geostationary Orbit: Legal, Technical and Political Issues Surrounding Its Use in World Telecommunications*," 16 CASE WEST. RESERVE J. INT. L. 223 (1984).

- Presentations at scientific conferences on outer space law and policy, including on issues related to orbital debris;[6]
- Comments in agency proceedings on a variety of space-related issues;[7]
- Submissions to Congress and the White House on key space law and policy issues;[8]
- Op-Eds commenting on U.S. policy related to orbital debris;[9] and

[6] James E. Dunstan and Bob Werb, *Legal and Economics Implications of Orbital Debris Removal: Comments of the Space Frontier Foundation*, DARPA Orbital Debris Removal (ODR) Request for Information for Tactical Technology Office (TTO), DARPA-SN-09-68 (Oct. 30, 2009); James E. Dunstan et al., *Doing Business in Space: This Isn't Your Father's (or Mother's) Space Program Anymore*, Space Manufacturing 13 (2001); James E. Dunstan, *Earth To Space: I Can't Hear You; Selling Off Our Future To The Highest Bidder*, Space Manufacturing 11 (1997); James E. Dunstan, *Is Launching a Rocket Still an Ultra-Hazardous Activity? Toward a Negligence Theory for Launch Activities*, Proceedings of the Eleventh Space Studies Institute/Princeton Conference on Space Manufacturing (1993); James E. Dunstan, *From Flag Burnings to Bearing Arms to States Rights: Will the Bill of Rights Survive a Trip to the Moon?*, Proceedings of the Tenth Princeton/AIAA/Space Studies Institute Conference on Space Manufacturing (1991); James E. Dunstan, *Funding the High Frontier: Old Lessons We Must Once Again Learn*, Proceedings of the Ninth Princeton/AIAA/Space Studies Institute on Space Manufacturing (1989); James E. Dunstan, *Generating Revenues in Space: Challenging Some of the Economic Assumptions of Space Exploitation*, Proceedings of the NASA Symposium on Lunar Bases and Space Professional Activities in the 21st Century (Apr. 1988).

[7] TechFreedom, Comments on Allocation of Spectrum for Non-Federal Space Launch Operations, ET Docket No. 13-115 (Sept. 10, 2021), https://techfreedom.org/wp-content/uploads/2021/09/TechFreedom-Reply-Comments-13-115-9-10-21.pdf (allocation of spectrum for non-federal space launches); Letter from TechFreedom to FCC (Nov. 2, 2020), https://techfreedom.org/wp-content/uploads/2021/03/TechFreedom-Letter-to-FCC-11-2-20.pdf (warning of danger of FCC granting "market access" to a company proposing very large satellites and licensed by a government (Papua New Guinea) which is not a signatory to the Liability Convention); TechFreedom, Comments on Rural eConnectivity Program, RUS–20–Telecom–0023 (Apr. 27, 2021), http://techfreedom.org/wp-content/uploads/2021/04/TF-Comments-USDA-4-27-21.pdf (urging that any grant for rural broadband deployment be technology neutral such as to allow satellite broadband providers to participate).

[8] TechFreedom, Comments on OSTP Request for Comment on: National Orbital Debris Research and Development Plan (Dec. 31, 2021), https://techfreedom.org/wp-content/uploads/2022/01/TechFreedom-Comments-OSTP-Orbital-Debris-Strat-Plan.pdf; Letter from TechFreedom to Senate Subcommittee on Space and Science (July 21, 2021), https://techfreedom.org/wp-content/uploads/2021/07/Letter-to-Senate-Space-Subcommittee-7-21-21.docx-1.pdf (concerning the loophole of allowing U.S. companies to get "flag of convenience" licenses from foreign jurisdictions).

[9] James E. Dunstan, *Who wants to step up to a $10 billion risk?,* SPACE NEWS (June 25, 2021), https://spacenews.com/op-ed-who-wants-to-step-up-to-a-10-billion-risk/; James Dunstan, *The FCC and Spectrum Policy: Sometimes It Hz So Bad,* TOWNHALL (Nov. 16, 2020), https://townhall.com/columnists/jamesdunstan/2020/11/16/the-fcc-and-spectrum-policy-sometimes-it-hz-so-bad-n2580049; Corbin Barthold, *Rival Wants Regulators to Cripple Elon Musk's Satellite Project*, THE BULWARK (Aug. 3, 2021), https://www.thebulwark.com/rival-wants-regulators-to-cripple-elon-musks-satellite-project/; James E. Dunstan, *Bring On the Space Barons* (Sept. 14, 2021), https://medium.com/@TechFreedom/bring-on-the-space-barons-e425129fbff6; James E. Dunstan, *Do we care about orbital debris at all?*, SPACE NEWS (Jan. 30, 2018), https://spacenews.com/op-ed-do-we-care-about-orbital-debris-at-all/; Berin Szóka & James E. Dunstan, *Space Property Rights: It's Time, and Here's Where to Start*, SPACE NEWS (Jan. 27, 2014),

- Podcasts.[10]

We are therefore well-versed in issues related to space policy and welcome the opportunity to comment on NASA's Moon to Mars Objectives.

II. You Can't Tweet Yourself to Mars

Before we delve into the details of the 50(!) listed Objectives, we must first comment on NASA's approach to collecting stakeholder input. The short timeframe of 17 days (originally 14 days) shows that NASA isn't particularly interested in thorough feedback. The fact that the submission format is a set of pull-down text boxes further evinces that NASA is not looking for detailed, cohesive responses, but rather hoping for short "attaboys" on its 50 objectives. We are left to drop a link in the "Additional Comments" section to point to these comments and cross our fingers that they will be read and considered in the same way that other federal agencies deal with comments from impacted stakeholders.

NASA is at its best when it steps out with bold visions to explore the heavens in anticipation of a human diaspora into the solar system. But NASA is at its worst when it becomes insular, rigid, and unwilling to hear dissenting (or even cautionary) voices.

The Rogers Report on the *Challenger* accident contained a section dedicated to "Flaws in the Decision Making Process" surrounding the launch of the Shuttle in 1986, and another entire chapter entitled "An Accident Rooted in History."[11] The report faulted NASA on a number of levels, but most importantly, chastised the agency for ignoring the written warnings about dangers with the O-rings of the solid rocket boosters.[12]

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https://spacenews.com/39294space-property-rights-its-time-and-heres-where-to-start/; James Dunstan & Berin Szóka, *Beware of Space Junk*, FORBES (Dec. 17, 2009), https://www.forbes.com/2009/12/17/space-junk-environment-global-opinions-contributors-berin-szoka-james-dunstan/?sh=6b7d6da16b6c.

[10] *Space Law! (Part 1)*, TECH POLICY PODCAST (Feb. 1, 2016), http://podcast.techfreedom.org/e/13-space-law-part-1/; *Space Law (Part 2) Property Rights in Space*, TECH POLICY PODCAST (Feb. 23, 2016), http://podcast.techfreedom.org/e/space-law-party-2-property-rights-in-space/; *Space Law (Part 3) Mining in Space*, TECH POLICY PODCAST (Mar. 1, 2016), http://podcast.techfreedom.org/e/33-space-law-part-3-mining-in-space/; *The New Space Race*, TECH POLICY PODCAST (Nov. 23, 2021), http://podcast.techfreedom.org/e/306-the-new-space-race/.

[11] PRESIDENTIAL COMM'N ON THE SPACE SHUTTLE CHALLENGER ACCIDENT, REP. ON THE SPACE SHUTTLE CHALLENGER ACCIDENT (1986), https://history.nasa.gov/rogersrep/genindex.htm.

[12] *Id.* ("The Commission has concluded that neither Thiokol nor NASA responded adequately to internal warnings about the faulty seal design.").

The report on the investigation of the *Columbia* accident was even more scathing, concluding that NASA suffered from "a broken safety culture,"[13] and that "the current Shuttle program culture is too insular."[14] This claim of NASA not listening to the input of others was not unique to 1986 (*Challenger*) nor 2003 (*Columbia*). An internal NASA assessment in 1999 found the following:

> The Shuttle Program was inappropriately *using previous success as a justification* for accepting increased risk; the Shuttle Program's a*bility to manage risk was being eroded* "by the desire to reduce costs;" the size and complexity of the Shuttle Program and NASA/contractor relationships *demanded better communication practices*; NASA's safety and mission assurance organization *was not sufficiently independent*; and "the workforce has received a conflicting message due to the emphasis on achieving cost and staff reductions, and the *pressures placed on increasing scheduled flights* as a result of the Space Station" [emphasis added]. The Shuttle Independent Assessment Team found failures of communication to flow up from the "shop floor" and down from supervisors to workers, deficiencies in problem and waiver-tracking systems, potential conflicts of interest between Program and contractor goals, and a general failure to communicate requirements and changes across organizations. In general, the Program's organizational culture was deemed "too insular."[15]

We are not suggesting that NASA's current efforts toward a return to the Moon and then on to Mars is doomed to catastrophic failure. Yet these prior external assessments of NASA's insularity and bouts of hubris should provide a stark warning that, no matter how many smart people work at NASA, outside input should always be welcomed, not stifled or disregarded.

In the movie *World War Z*, Israel is the first country to recognize the zombie outbreak. The movie's main character, played by Brad Pitt, travels to Israel and asks Mossad Chief Jurgen Warmbrunn how Israeli intelligence figured it out. He responds with the Tenth Man Rule:

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[13] COLUMBIA ACCIDENT INVESTIGATION BOARD at 184, REPORT VOLUME 1 (2003), http://s3.amazonaws.com/akamai.netstorage/anon.nasa-global/CAIB/CAIB_highres_full.pdf.

[14] *Id.* at 187.

[15] *Id.* at 179 (*quoting* OFFICE OF SPACE FLIGHT, EXECUTIVE SUMMARY OF NATIONAL AERONAUTICS AND SPACE ADMINISTRATION SPACE SHUTTLE INDEPENDENT ASSESSMENT TEAM, REPORT TO ASSOCIATE ADMINISTRATOR, CAIB DOCUMENT CTF017-0169 (1999) (emphasis in original)).

> If nine of us who get the same information arrived at the same conclusion, it's the duty of the tenth man to disagree. No matter how improbable it may seem. The tenth man has to start thinking about the assumption that the other nine are wrong.[16]

The Tenth Man Rule is not a cinematic trope (although the name is somewhat apocryphal), but rather is rooted in history. The Israeli military established an entire office following the 1973 Yom Kippur War to act as a devil's advocate, challenging the groupthink that can drive decision-making. As one commentator notes:

> In the tenth man rule, there is a decision to be made in the middle. Although this decision is the right one, it is important to see the negative aspects of every right, but we have difficulty seeing the negative aspects of choices we consider right. For this reason, a volunteer "consistently" rejects the decision accepted by the nine people at the table and explains to the table the consistent aspects of the opposing view he or she rejects.[17]

Having watched the development of the latest NASA attempt to return humans to the Moon, and then move out to Mars, and particularly having watched the video presentation of the current Objectives, we can't help but wonder is NASA lacks a proper devil's advocate, a Tenth Man, to disagree with the collective conclusions reached by NASA as how to proceed. These comments may help NASA to look into the collective mirror, and soberly assess what it has done, and whether its Objectives set out a viable path forward.

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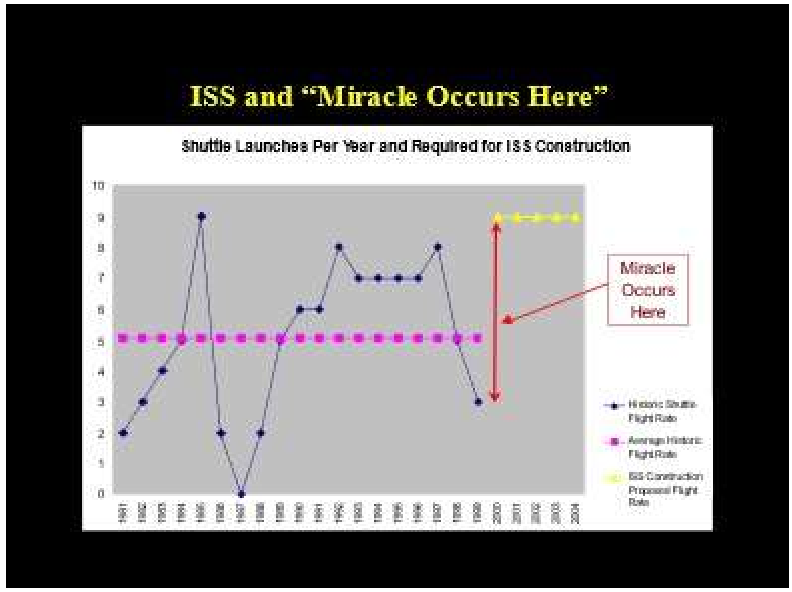
[16] *See 10th Man Israel's Strategy - World War Z*, YOUTUBE (Oct. 29, 2016), https://www.youtube.com/watch?v=k25X3KY_m8k.

[17] *Key Person of Major Decisions in Israel: The Tenth Man*, NEWS TEXT AREA (May 8, 2022), https://newstextarea.com/key-person-of-major-decisions-in-israel-the-tenth-man/.

Similarly, these Objectives seem to chart a rigid technological development path that could be counterproductive. NASA should never rely on future events or technologies to miraculously appear. It did so once, in its planning of ISS construction, when it assumed that the Space Shuttle would fly, on average, nine times per year during the ISS construction phase, when it had only made nine flights once in its history, and when the historical flight rate of the Shuttle was five flights per year. At the same time, NASA's Objectives and technology roadmap must be flexible enough to account for "black swan" events or technologies that appear during the endeavor.[18] For example, when SLS and Orion were announced in 2011, SpaceX's Starship was little more than an idea of Elon Musk. SpaceX has proceeded at a rapid pace to develop Starship, and if successful, it will be a black swan technology that easily will supplant both SLS and Orion as the backbone for a return to the Moon and on to Mars. It could represent the ultimate in black swans for the future of space exploration and development, one that would completely reshape the industry forever.[19] We are concerned whether NASA will be willing to revisit and modify both the 50 Objectives and the technology roadmap if such events were to unfold.



J. Dunstan, "Miracles Occurring Now," Banquet Address, Return to the Moon II Conference, July 20, 2000.

III. Apollo Redux Is a Grave Mistake

NASA's architectural and programmatic approach to returning to the Moon and putting humans on Mars is cut from the same cloth as the Apollo program. It is a top-down approach, rife

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[18] *See* NASSIM NICHOLAS TALEB, THE BLACK SWAN: THE IMPACT OF THE HIGHLY IMPROBABLE (2007).

[19] *See* Hardy Graupner, *Elon Musk's Starship could change the space business forever*, DEUTSCHE WELLE (Feb. 10, 2022), https://www.dw.com/en/elon-musks-starship-could-change-the-space-business-forever/a-60733091 ("The SpaceX founder has said his groundbreaking megarocket could be orbital within months. Some say Starship is the beginning of the end for space firms that fail to see its potential.").

with central planning, dependent on multiple other government programs, many of which are behind schedule, and it places science as king above all else. The message is simple:

"Dear Congress: Please give NASA many billions more each year and they'll do great things. Thank you."

This approach has failed every single time since Apollo. Most notably, in the closest analog to the Artemis program, an "Apollo on steroids" approach failed with President George H. W. Bush's 1989 Space Exploration Initiative (SEI).[20] Thor Hogan summed up the failure of SEI in his book *Mars Wars: The Rise and Fall of the Space Exploration Initiative*:

> The rise of SEI and its eventual demise represents one of the landmark episodes in the history of the American space program—ranking with the creation of NASA, the decision to go to the Moon, the post-Apollo planning process, and the space station decision. The story of this failed initiative is one shaped by key protagonists and critical battles. It is a tale of organizational, cultural, and personal confrontation. Organizational skirmishes involved the Space Council versus NASA, the White House versus congressional appropriators, and the Johnson Space Center versus the rest of the space agency—all seeking control of the national space policy process. Cultural struggles pitted the increasingly conservative engineering ethos of NASA against the "faster, better, cheaper" philosophy of a Space Council looking for innovative solutions to technical problems. Personality clashes matched Vice President Dan Quayle and Space Council Executive Secretary Mark Albrecht against NASA Administrator Dick Truly and Johnson Space Center Director Aaron Cohen. In the final analysis, the demise of SEI was a classic example of a defective decision-making process—one that lacked adequate high-level policy guidance, failed to address critical fiscal constraints, developed inadequate programmatic alternatives, and garnered no congressional support. Some space policy experts have argued that SEI was doomed to fail, due primarily to the immense budgetary pressures facing the nation during the early 1990s. This book will argue, however, that the failure of the initiative was not predetermined; instead, it was the result of a deeply flawed policy

[20] *See* Steven Dick, *The Space Exploration Initiative*, NASA, https://history.nasa.gov/sei.htm (last visited June 2, 2022).

> process that failed to develop (or even consider) policy options that may have been politically acceptable given the existing political environment.[21]

A recent NASA OIG Report appears to signal that NASA's Artemis program may be headed toward the same failure mode.

> NASA's three initial Artemis missions, designed to culminate in a crewed lunar landing, face varying degrees of technical difficulties and delays heightened by the COVID-19 pandemic and weather events that will push launch schedules from months to years past the Agency's current goals. With Artemis I mission elements now being integrated and tested at Kennedy Space Center, we estimate NASA will be ready to launch by summer 2022 rather than November 2021 as planned. Although Artemis II is scheduled to launch in late 2023, we project that it will be delayed until at least mid-2024 due to the mission's reuse of Orion components from Artemis I. While the Advanced Exploration Systems (AES) Division—which includes HLS, Gateway, and next-generation spacesuits—is working on an integrated master schedule (IMS) for Artemis III that incorporates Exploration Systems Development (ESD) Division programs—SLS, Orion, and Exploration Ground Systems—the draft version does not include information on programs critical to Artemis that are outside of AES and ESD. Given the time needed to develop and fully test the HLS and new spacesuits, we project NASA will exceed its current timetable for landing humans on the Moon in late 2024 by several years.
>
> In addition, NASA lacks a comprehensive and accurate cost estimate that accounts for all Artemis program costs. For FYs 2021 through 2025, the Agency uses a rough estimate for the first three missions that excludes $25 billion for key activities related to planned missions beyond Artemis III. When aggregating all relevant costs across mission directorates, NASA is projected to spend $93 billion on the Artemis effort up to FY 2025. We also project the current production and operations cost of a single SLS/Orion system at $4.1 billion per launch for Artemis I through IV, although the Agency's ongoing initiatives aimed at increasing affordability seek to reduce that cost. Multiple factors contribute to the high cost of ESD programs, including the use of sole-source, cost-

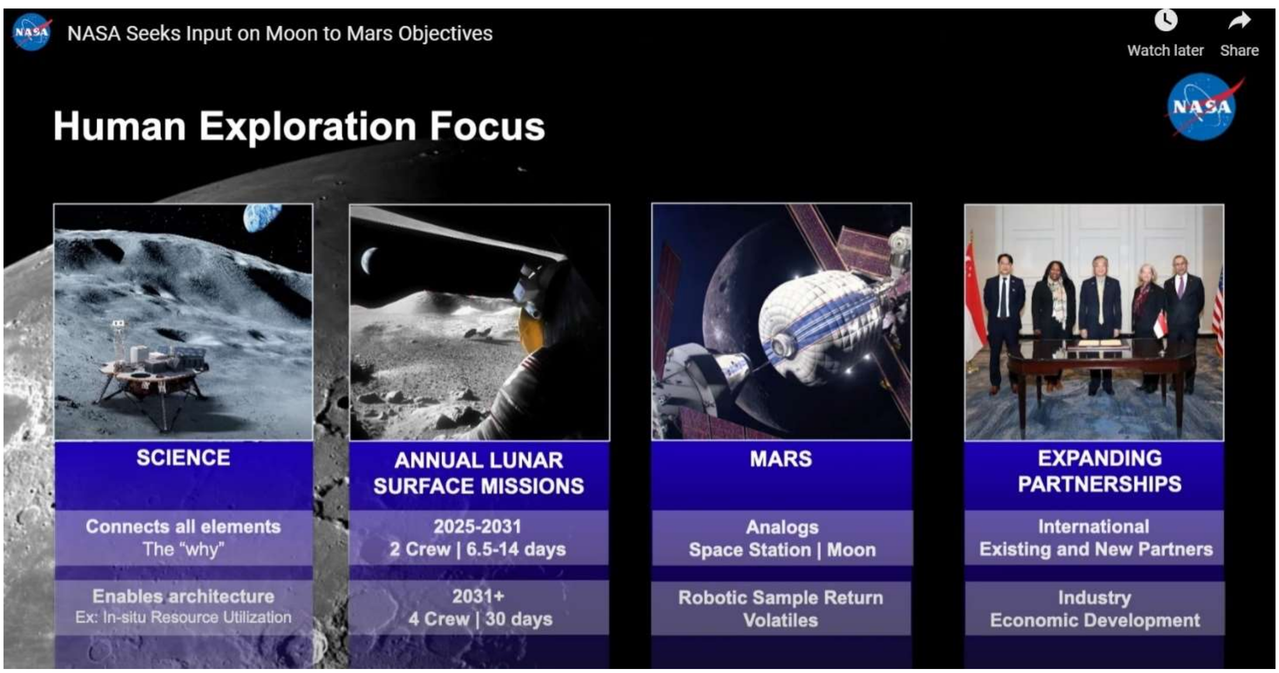
[21] Thor Hogan, *Mars Wars: The Rise and Fall of the Space Exploration Initiative* at 2, NASA (May 2007), https://history.nasa.gov/sp4410.pdf (footnote omitted).

> plus contracts; the inability to definitize key contract terms in a timely manner; and the fact that except for the Orion capsule, its subsystems, and the supporting launch facilities, all components are expendable and "single use" unlike emerging commercial space flight systems. Without capturing, accurately reporting, and reducing the cost of future SLS/Orion missions, the Agency will face significant challenges to sustaining its Artemis program in its current configuration.[22]

So, what is wrong with NASA's approach to returning to the Moon and then on to Mars? We have a few ideas.

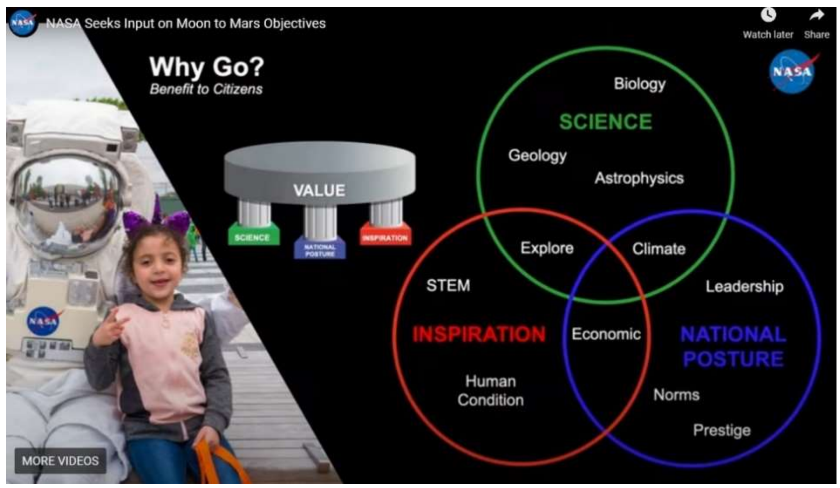
A. Placing Science at the Center of Human Outreach into the Solar System Is a Non-Starter

We were struck during the video presentation of the Objectives of how much the science objectives were emphasized, and how "industry" and "economic development" were shoved off to the side. Below is a screenshot from the presentation.



[22] NASA OFFICE OF INSPECTOR GENERAL, NASA'S MANAGEMENT OF THE ARTEMIS MISSIONS at 3-4, (2021), https://oig.nasa.gov/docs/IG-22-003.pdf.

The role of science in human exploration has always been debated. One thing has been clear for many decades, if not centuries: the lure of scientific discovery alone will never garner sufficient political or public support to result in government appropriations necessary to carry out major exploration projects. When President Thomas Jefferson underwrote an expedition to explore the lands acquired by the United States in the Louisiana Purchase, he sent Meriwether Lewis detailed instructions as to the purposes of the expedition. While Jefferson was interested in acquiring scientific knowledge of the area (indeed, it can be argued that he was our most scientifically literate president), "The object of your mission is to explore the Missouri river, & such principal stream of it, as, by it's [sic] course & communication with the water of the Pacific Ocean may offer the most direct & practicable water communication across this continent, for *the purposes of commerce*."[23]



The application of this reasoning to outer space exploration dates to the end of the Apollo program, when Apollos 18 and 19 were cancelled because a lack of continued support for the program. Once the “national posture,” “prestige,” and “leadership” goals of the Apollo program were obtained by beating the Soviets to land a human on the Moon, support for follow-on missions to the Moon to gain additional science knowledge all but evaporated. Worst yet, NASA became almost instantly rudderless, as having won the “space race,” its next great “mission” was unclear. Hogan describes what post-Apollo planning looked like, and why it failed to produce an actual push to either continue human missions to the Moon or onward to Mars:

> [In February 1969] President Nixon asked Vice President Spiro Agnew to chair a Space Task Group (STG) created to provide a definitive recommendation regarding the course the space program should take during the post-Apollo period.

[23] Letter from Thomas Jefferson to Meriwether Lewis (June 20, 1803), https://www.loc.gov/exhibits/lewisandclark/transcript57.html.

> The other members of the STG were Secretary of the Air Force Robert Seamans, NASA Administrator Thomas Paine, and Presidential Science Advisor Lee DuBridge. Joan Hoff argues in *Spaceflight and the Myth of Presidential Leadership* that the creation of the STG was "a mixed blessing for NASA because Paine assumed almost immediately that Agnew's personal and public support of a 'manned flight to Mars by the end of this century' would carry the day inside the White House and BOB [Bureau of Budget], when nothing could have been further from the truth." At an early STG meeting, Paine pushed forward based on this incorrect assumption by contending that the space agency needed a new program to rally around. Agnew was supportive, stating that NASA needed an "Apollo for the seventies." As the primary policy entrepreneurs supporting a human mission to Mars, Paine and Agnew selected an approach for post-Apollo planning that did not mesh with either President Nixon's basic ideology or changes in the national mood regarding space exploration. Hoff writes "*Nixon was concerned about scientific-technological programs that might stress engineering over science, competition over cooperation, civilian over military, and adventure over applications*…[and his] emphasis on frugality in government spending prompted caution on his part in endorsing any effort in space." Public sentiment toward the space program had also begun to shift, with increasing concerns that the government had misplaced priorities. A Gallup Poll conducted in July 1969, at the time of the Apollo 11 mission, indicated that only 39% of Americans were in favor of U.S. government spending to send Americans to Mars, while 53% were opposed. Thus, Paine and Agnew were pushing for a large new Apollo-like commitment despite the fact that there appeared to be little or no support for such an undertaking within the White House or the mass public.[24]

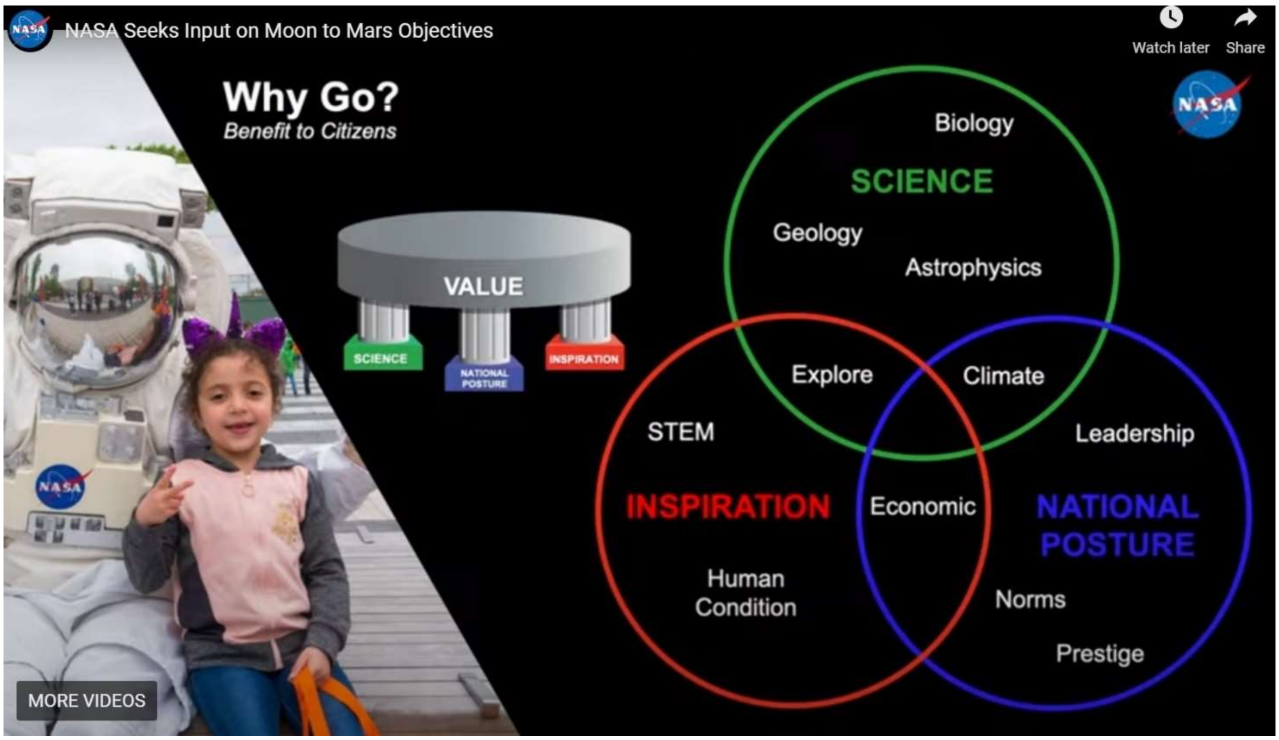
Previous planning bodies, even though they've been unsuccessful in garnering sufficient support for humans in deep space, at least recognized that a "science first" approach was a nonstarter. The 1986 National Commission on Space report, *Pioneering the Space Frontier: An Exciting Vision of Our Next Fifty Years in Space*, for example, listed three overarching goals for space exploration and development: "'pulling-through' advances in science and technology of critical importance to the Nation's future economic strength and national security…providing direct economic returns from new space-based enterprises that capitalize upon broad, low-cost access to space, and…opening new worlds on the space frontier, with vast resources that

[24] Thor Hogan, *Mars Wars: The Rise and Fall of the Space Exploration Initiative*, NASA, May 2007, at 21–22, https://history.nasa.gov/sp4410.pdf (footnotes omitted).

can free humanity's aspirations from the limitations of our small planet of birth."[25] While science was a part of those objectives, economic returns from space initiatives were the key component. A return to "science as king" as a top-level objective undoubtedly will signal the death of this endeavor.

B. The Deemphasis of Economic Drivers for Space Exploration Is Contrary to NASA's Statutory Mandate and U.S. Space Policy

Hand in hand with elevating the science goals of a human return to the Moon in the Objectives is a de-emphasis, almost a burying, of the economic benefits to be gained from humans in space. Let's revisit the previous screenshot from the video presentation.



Note how "science" has its own circle of influence in the decision-making process, while economics is relegated to a small intersection of the "inspiration" and "national posture" circles of

[25] NATIONAL COMMISSION ON SPACE, PIONEERING THE SPACE FRONTIER: AN EXCITING VISION OF OUR NEXT FIFTY YEARS IN SPACE 19 (1986).

influence.[26] Not only is this wrong from a policy standpoint, but it also flies in the face of NASA's statutory mandate.

We begin with Section 102(c) of the NASA Act, which states: "The Congress declares that the general welfare of the United States requires that the National Aeronautics and Space Administration (as established by title II of this Act) seek and encourage, to the maximum extent possible, the fullest commercial use of space."[27] In 1990, Congress added Section 203(a) to the NASA Act, which states that "[t]he Administration, in order to carry out the purpose of this Act, shall—(4) seek and encourage, to the maximum extent possible, the fullest commercial use of space; and (5) encourage and provide for Federal Government use of commercially provided space services and hardware, consistent with the requirements of the Federal Government."[28] In 1998 Congress passed the Commercial Space Act of 1998, which uses the term "commercial" 72 times, including a requirement that "the Federal Government shall acquire space transportation services from United States commercial providers whenever such services are required in the course of its activities. To the maximum extent practicable, the Federal Government shall plan missions to accommodate the space transportation services capabilities of United States commercial providers."[29] Finally, in 2007, Congress added Section 20303(a), which directed that "[t]he Administration shall be a full participant in any interagency effort to promote innovation and economic competitiveness through near-term and long-term basic scientific research and development and the promotion of science, technology, engineering, and mathematics education, consistent with the Administration's mission, including authorized activities."[30]

The current National Space Policy echoes Congress's call to ensure that the economic impact of space activities and use of commercial capabilities be front and center in NASA's mission:

[26] It is interesting to note that according to this Venn diagram, STEM education doesn't even intersect with science. Is NASA going to rename STEM to "TEM" and drop the educational component of gathering scientific knowledge? Or is it a recognition that science is so important that NASA scientists can't be bothered to engage in the education of the next generation of scientists?

[27] 51 U.S.C. § 20102. Subsection (c) was added by the National Aeronautics and Space Administration Authorization Act, 1985, Pub. L No. 98-361, § 110(a), 98 Stat. 422, 426 (Jul. 16, 1984).

[28] National Aeronautics and Space Administration Authorization Act, Fiscal Year 1991, Pub. L. No. 101–611, § 107, 104 Stat. 3188, 3197 (Nov. 16, 1990).

[29] Commercial Space Act of 1998, Pub. L. 105–303, § 201 (1998), codified at 51 U.S.C. § 50131(a).

[30] Pub. L. 110–69, title II, § 2001(a), (b), (c), (e), 121 Stat. 582 (2007).

> Since America's first steps on the Moon, the United States has utilized its space capabilities to stimulate economic growth, enhance the quality of life for all Americans and people around the world, and advance the principles of democracy, human rights, and economic freedom.
>
> The United States shall: Extend human economic activity into deep space by establishing a permanent human presence on the Moon, and, in cooperation with private industry and international partners, develop infrastructure and services that will enable science-driven exploration, space resource utilization, and human missions to Mars.[31]

A change in presidential administrations has not changed this emphasis on the economic development of outer space.

> We are in a historic moment: space activities are rapidly accelerating, resulting in new opportunities in multiple sectors of society, as well as new challenges to U.S. space leadership, global space governance, the sustainability of the space environment, and safe and secure space operations. Burgeoning U.S. space activities are a source of American strength at home and abroad—*from providing tangible economic and societal benefits to Americans* to expanding our network of alliances and partnerships.[32]

It is against this statutory and policy backdrop that the 50 Objectives barely reference the economic benefits from a robust and successful Moon and Mars endeavor. We do note the Lunar Infrastructure (RI) Goal to "Create Global Lunar Utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence on the lunar surface for a robust lunar economy without NASA as the sole user, while accomplishing Mars testing and science objectives."[33] We also note the reference in the Glossary of Terms to

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[31] NATIONAL SPACE POLICY OF THE UNITED STATES OF AMERICA 1, 5 (Dec. 9, 2020), https://trumpwhitehouse.archives.gov/wp-content/uploads/2020/12/National-Space-Policy.pdf.

[32] THE WHITE HOUSE, UNITED STATES SPACE PRIORITIES FRAMEWORK 3 (2021), https://www.whitehouse.gov/wp-content/uploads/2021/12/United-States-Space-Priorities-Framework-_-December-1-2021.pdf.

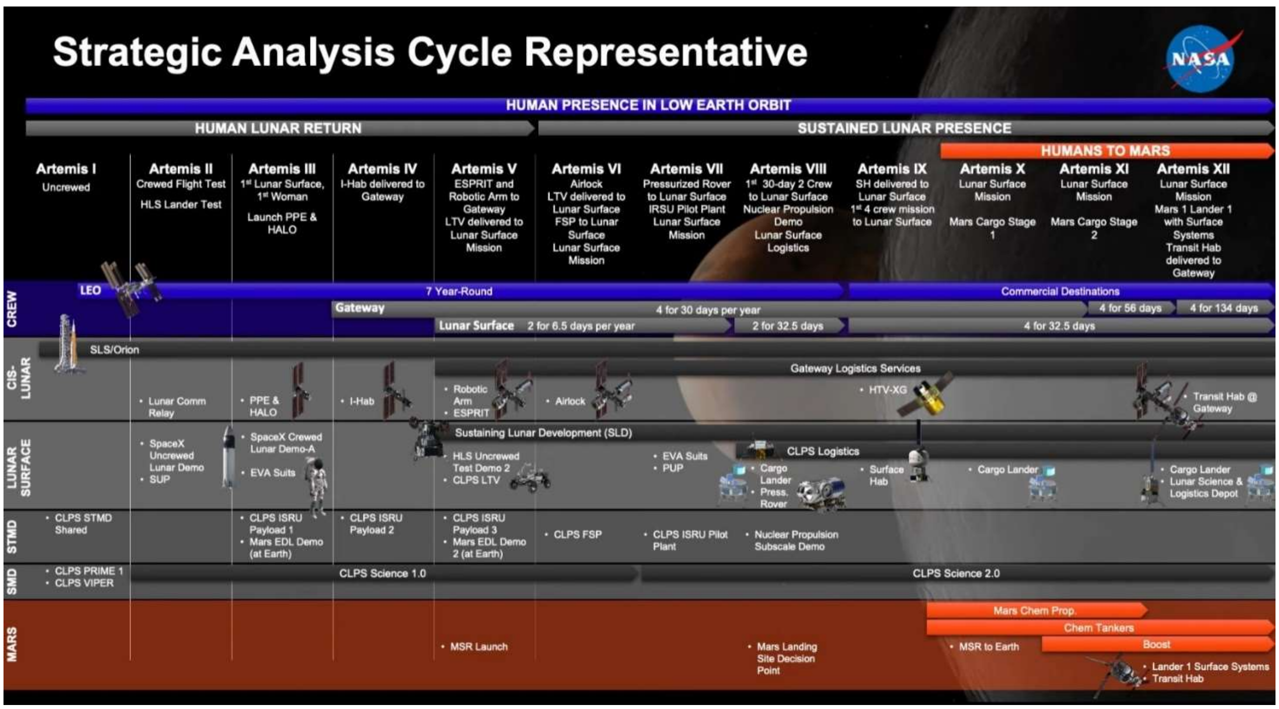
[33] *See also* Feedback on the draft Moon to Mars Objectives, NASA, https://socialforms.nasa.gov/m2m-objectives (Goal LI-3 states: "Demonstrate autonomous construction, precision landing, surface transportation, industrial scale ISRU and Advanced Manufacturing capabilities in support of future continuous human lunar presence and a robust lunar economy.") (last visited June 2, 2022).

"Industry Collaboration: collaborate with commercial partners to create most effective solutions and achieve common goals and objectives."

But those fleeting references appear aspirational at best, and most likely an output from NASA's activities, rather than an input that is "baked into" the decision-making process for a successful human Moon and Mars endeavor. And one Objective and one reference in a glossary are lost in the overall drumbeat of science being the driver for a return to the Moon and on to Mars.

C. Reliance on Government-Built Systems Ignores Commercial Capabilities and Risks Ultimate Failure

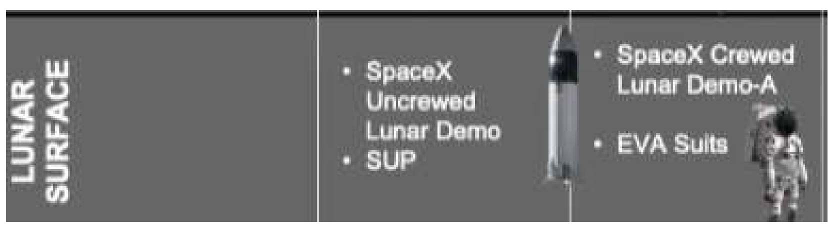
There exists a major disconnect from reality in the Objectives, in that they rely almost exclusively on government-built systems (both current and future), with only marginal input from the commercial sector. Again, a screenshot from the presentation brings this home.



In this graphic, the success of the overall project is totally reliant on SLS, Orion, and a Lunar Gateway, all government-built hardware projects. We've already mentioned the NASA OIG Report estimating that the "current production and operations cost of a single SLS/Orion system *at $4.1 billion per launch for Artemis I through IV*." That same Report concludes that the Lunar

Gateway "will likely not be available for a 2024 lunar landing due to still-evolving requirements." The NASA OIG also indicated that the projected $3.592 billion budget for the Lunar Gateway may understate the ultimate cost by a considerable amount. Moreover, what began as a firm-fixed-price contract for the HALO element has now morphed into "a sole-source undefinitized contract with only its design phase definitized 10 months later as a cost-plus-incentive-fee due to anticipated future design changes."[34] The Report concludes:

> We anticipate further schedule delays and cost increases due to additional undefined requirements, adjustments to projected budgets, and technical challenges. As of July 2020, over 50 requirements remain to be determined or resolved for areas such as the amount of storage needed. Moreover, given a projected reduction in funding for FYs 2021 through 2025, the Gateway Program made the decision to eliminate a second U.S. Habitation Module from its configuration, causing the HALO to accommodate medical and crew hygiene functions originally planned for the second module. HALO also continues to experience other technical challenges—including humidity control, especially when the crew is exercising; space needed for the layout of the crew's exercise area; and identifying a compatible lighting, video, and audio system—which may negatively affect HALO's schedule and cost.[35]



Meanwhile, the only true commercial component in this entire architecture appears to be the SpaceX Human Landing System (HLS) lunar lander, awarded through a firm-fixed-price contract for $2.89 billion,[36] and potentially surface spacesuits. But that

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[34] NASA OFFICE OF INSPECTOR GENERAL, NASA'S MANAGEMENT OF THE GATEWAY PROGRAM FOR ARTEMIS MISSIONS 18 (2021), https://oig.nasa.gov/docs/IG-21-004.pdf The report goes on to note: "NASA's experience has shown that the longer the government waits to finalize contract costs, the less incentive the contractor has to control its costs, creating a potential for wasted taxpayer dollars." *Id.* at 22.

[35] *Id.*

[36] *See* Monica Witt & Jena Rowe, *As Artemis Moves Forward, NASA Picks SpaceX to Land Next Americans on Moon*, NASA (Apr. 16, 2021), https://www.nasa.gov/press-release/as-artemis-moves-forward-nasa-picks-spacex-to-land-next-americans-on-moon.

represents an extremely small part of the overall systems that will be called upon to return humans to the Moon.

D. A Lack of Emphasis on Commercialization and Industrial Development Raises Serious National Security Concerns

The first space race pitted the United States against the Soviet Union to see which could first place humans on the Moon as a proxy for which governing system was superior. The next space race will be between the United States and China to see which can best make use of the vast resources of space and leverage those capabilities to elevate its position on the world stage.

> China's goal to establish a leading position in the economic and military use of outer space, or what Beijing calls its "space dream," is a core component of its aim to realize the "great rejuvenation of the Chinese nation." In pursuit of this goal, China has dedicated high-level attention and ample funding to catch up to and eventually surpass other spacefaring countries in terms of space-related industry, technology, diplomacy, and military power.
>
> China views space as critical to its future security and economic interests due to its vast strategic and economic potential. Moreover, Beijing has specific plans not merely to explore space, but to industrially dominate the space within the moon's orbit of Earth. China has invested significant resources in exploring the national security and economic value of this area, including its potential for space-based manufacturing, resource extraction, and power generation, although experts differ on the feasibility of some of these activities.[37]

A set of Objectives which prioritizes science over industrial development runs the risk of handing the Moon and Mars to China or other adversaries who are poised to benefit from an industrialized cislunar region, and who focus their resources on positioning themselves to be the first movers in space commerce.

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[37] U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION, REPORT TO CONGRESS OF THE U.S.-CHINA ECONOMIC AND SECURITY REVIEW COMMISSION 16 (2019), https://www.uscc.gov/sites/default/files/2019-11/2019%20Annual%20Report%20to%20Congress.pdf.

E. NASA Must Use Innovative Programs and Contracting Methods to Bring Down the Cost of Taking Humans to the Moon and Mars

Is an architecture so dependent on traditional cost-plus/government run hardware sustainable? We think not. Congressional appropriations to NASA have fallen short of Administration requests in each of the last few years,[38] and it is highly unlikely that Congress will play catch-up with NASA's budget to keep it on course for a human return to the Moon, given the current economy and rampant inflation. The only viable solution to the "budget death spiral" is for Artemis to wean itself off cost-plus/government-built hardware and instead purchase services from commercial providers such as SpaceX, Blue Origin, and others.

Procurement programs fashioned after the Commercial Orbital Transportation Services (COTS) program (with some changes as noted below) are the only viable way out for NASA. The COTS Final Report found the following, which can be applied to Artemis:

- Government seed money was highly leveraged
  - Commercial partners funded over 50% of COTS development costs
- Fixed price milestone payments maximized incentives to control cost and minimize schedule delays
- Minimum firm requirements along with commensurate Government oversight were key to fostering innovation and reducing life cycle development costs
  - Goals (vs. requirements) were established to open trade space and optimize design
  - Firm requirements were identified only where necessary to assure the safety of the ISS and crew
  - ISS interface requirements evolved over time and were coordinated in a collaborative manner with the commercial partners
- A portfolio of multiple partners with different capabilities assured a balanced approach to technical and business risks

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[38] *See NASA's FY 2021 Budget*, THE PLANETARY SOCIETY, https://www.planetary.org/space-policy/nasas-fy-2021-budget#:~:text=NASA's%20budget%20for%20fiscal%20year,months%20into%20the%20fiscal%20year ("The President's Budget Request (PBR), released on 10 February 2020, had proposed $25.2 billion for FY 2021, an increase of 12%. The increase almost fully directed toward supporting a 2024 crewed lunar return, with over $3 billion proposed for human landing systems. Ultimately, Congress provided only 25% of those requested funds, all but guaranteeing that a lunar return will not happen by 2024.") (last visited June 2, 2022).

    - Increased the chances of at least one successful partner
    - Market forces kept development and operational costs in check
  - Commercial friendly intellectual property/data rights and limited termination liability encouraged investment of private capital
  - NASA commitment to purchase operational services greatly improves the ability for companies to raise funds.[39]

The 2017 Air Force Fast Space Study summarized the importance of using Other Transaction Authority (OTA) as follows:

> FINDING [F.4] Traditional USG acquisition methods, or a traditional operationally-focused acquisition office, are likely to fail at effectively partnering with commercial space industry. The majority of leading US commercial firms have made it very clear they are not interested in traditional USG FAR-contract-based approaches to accelerate private development of ULCATS systems. Traditional USG methods of buying launch services have been optimized for removing residual levels of risk, not for lowering costs. The current USG methods of mission assurance are completely rational in an industry where the cost of the spacecraft is several times the cost of the launch and the consequences of a failed launch can be catastrophic to national security. USG agencies that implement these important methods of mission assurance have cultures, processes, and values that are in complete alignment with this philosophy of space launch. These same processes, cultures and values—which are critical to these agencies' ability to eliminate the residual risk from expendable launch vehicles—are showstopping-barriers to the commercial innovation process. Any ULCATS initiative that proposes to leverage commercial innovation will fail if it is given to a USG agency that develops or acquires systems using traditional governmental methods, or processes, or has a traditional USG development or acquisition culture.[40]

NASA should also look at other innovative approaches to tap into academia and the commercial sector to develop the core technologies necessary for a human return to the Moon and then

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[39] *See COTS: Final Report*, NASA, https://www.nasa.gov/content/cots-final-report (last visited June 2, 2022).

[40] AIR UNIVERSITY, MAXWELL AFB, FAST SPACE: LEVERAGING ULTRA LOW-COST SPACE ACCESS FOR 21ST CENTURY CHALLENGERS 33–34 (2017), https://www.airuniversity.af.edu/Portals/10/Research/Space-Horizons/documents/Fast%20Space_Public_2017.pdf (declassified version).

on to Mars. A greater emphasis should be placed on the use of prizes.[41] NASA has made limited use of prizes, yet the return has been great.

> NASA engaged the public with 56 public prize competitions and challenges and 14 citizen science and crowdsourcing activities over fiscal years 2019 and 2020. NASA awarded $2.2 million in prize money, and members of the public submitted over 11,000 solutions during that period.
>
> "NASA's accomplishments have hardly been NASA's alone. Tens of thousands more individuals from academic institutions, private companies, and other space agencies also contribute to these solutions. Open innovation expands the NASA community and broadens the agency's capacity for innovation and discovery even further," said Amy Kaminski, Prizes, Challenges, and Crowdsourcing program executive at NASA Headquarters in Washington. "We harness the perspectives, expertise, and enthusiasm of 'the crowd' to gain diverse solutions, speed up projects, and reduce costs.[42]

DARPA's Grand Challenge in 2004–2005 was the catalyst for a breakthrough in highly capable autonomous robotics, the fruits of which we are seeing in society at large with the emergence of self-driving automobile technologies.

> DARPA ran its pathbreaking Grand Challenge with the goal of spurring on American ingenuity to accelerate the development of autonomous vehicle technologies that could be applied to military requirements. No team entry successfully completed the designated DARPA Grand Challenge route from Barstow, CA, to Primm, NV, on March 13, 2004. The event offered a $1 million prize to the winner from among 15 finalists that emerged from a qualifying round at the California Speedway, but the prize went unclaimed as no vehicles were able to complete the difficult desert route.

[41] For a history of the value of prizes to push technology forward, *see* Ken Davidian, *Prizes, Prize Culture, and NASA's Centennial Challenges*, DMG ASSOCIATES (June 26, 2006), http://commercialspace.pbworks.com/f/Prizes,+Prize+Culture,+and+NASA%27s+Centennial+Challenges.pdf.

[42] Karen James, *Public Provides NASA with New Innovations through Prize Competitions, Crowdsourcing, Citizen Science Opportunities*, NASA (Jan. 31, 2022), https://www.nasa.gov/solve/open_innovation.

> A year later, on October 8, 2005, another round of the Grand Challenge was held in the desert Southwest near the California/Nevada state line. The Stanford Racing Team won the $2 million prize with the winning time of 6 hours, 53 minutes. A total of five teams completed the Grand Challenge course which was 132 miles over desert terrain. These challenges helped to create a mindset and research community that a decade later would render fleets of autonomous cars and other ground vehicles a near certainty for the first quarter of the 21st century.[43]

In addition to generating real technologies and answers to critical questions in space exploration, prizes also act to draw more people into the development loop, and if run properly, they draw the public at large into the ecosystem, helping to build more support for the overall program.

Innovative approaches to contracting and driving technology development are the only successful model for achieving a human return to the Moon and then exploration of Mars.[44] It is clear from prior failures that traditional top-down, centrally planned architectures will ultimately fail under their own weight. Unfortunately, NASA appears to be regressing to an Apollo Redux model with these Objectives. Without a hard turn toward commercialization and putting the economics first, we fear this will be yet another doomed attempt to return humans to deep space.

IV. Specific Comments to the Objectives

Having set forth our beliefs about what must be the first principles of Artemis, we now turn to responding to each of the 50 Objectives. Each of these responses is heavily colored by our overall skepticism of the current architecture. Each has been pasted into the text boxes at https://socialforms.nasa.gov/m2m-objectives. We also change from footnote-style citations to brief-style citations because the socialforms text boxes do not support footnotes.[45]

[43] *See The Grand Challenge*, DARPA, https://www.darpa.mil/about-us/timeline/-grand-challenge-for-autonomous-vehicles (last visited June 2, 2022).

[44] The success of COTS was further validated in the 2017 FAST SPACE study conducted by Air University at Maxwell AFB. AIR UNIVERSITY, MAXWELL AFB, *supra* note 40, at 28 ("The NASA COTS program demonstrated a factor of 8x reduction in the development cost of the Falcon 9 launch vehicle between the actual costs and what had been estimated with NASA Air Force Cost Model (NAFCOM)."). The author of these comments provided significant input into the government commercial regulatory systems analysis of that report.

[45] *See supra* Section II.

A. *Transportation and Habitation Goal*

Develop and demonstrate an integrated system of systems to conduct a campaign of human missions to the Moon and Mars, living and working on the lunar and Martian surface, and a safe return to Earth.

TH1: Develop cislunar systems that crew can routinely operate to lunar orbit and lunar surface for extended durations.

Response: Agree, partially. We object to the term "develop" because that connotes a program in which NASA does the development. We suggest you modify this Objective to read "Develop and/or Acquire." This objection stands for virtually all of our responses. The key component to this Objective is *routine*. Routine access to the Moon cannot be achieved if each flight costs $4 billion, per the recent NASA OIG Report. If SLS/Orion is absolutely required for Artemis I-IV, NASA *must* move today to begin to transition to a commercial option in order to achieve routine access to the Moon. Every effort should be made to utilize fixed-cost contracts such as the SpaceX HLS contract.

TH2: Develop systems that can routinely deliver large surface elements to the lunar surface.

Response: We object to the term "develop" because that connotes a program in which NASA does the development. We suggest you modify this Objective to read "Acquire." NASA should use cargo delivery to the Moon in the same way it used cargo to ISS to develop the COTS program, which has now matured into commercial delivery of crews to ISS. NASA should purchase cargo delivery services wherever possible and do so in as flexible a manner as possible to allow for new and innovative technologies to be used. NASA can afford to take more risk with cargo than it can with human flights, and should leverage this to help drive down the costs to the lunar surface, first for cargo, and eventually for humans.

TH3: Develop systems to allow crew to live and operate safely on the lunar surface and lunar orbit for extended periods of time with scalability to continuous presence to visit areas of interest for scientific research, conduct Mars analog activities, support industrial utilization, and conduct utilization activities.

Response: Agree. We do object to the hierarchy of uses in the wording of this Objective, where "scientific research" is first, and "industrial utilization" is at the end. If science gets to veto industrial utilization, or if it gets the primary allocation of resources (economic or otherwise), Artemis will fail. More important, given what is at stake from a national security standpoint if other nations prioritize industrial development of the Moon, this hierarchy could lead to a serious lapse in leadership in space for the United States.

TH4: Develop a habitation system for crew in deep space for extended durations, enabling future missions to Mars.

Response: It remains unclear whether a lunar orbiting habitation system is required. The current Artemis configuration continues to call for a Lunar Gateway, but problems with that program, and the possibility of utilizing large commercial transportation nodes such as the SpaceX Starship, call into question the need for a permanent Lunar Gateway. NASA should remain flexible in its architectural approach such that it can jettison the Lunar Gateway if cheaper and more near-term alternatives appear.

TH5: Develop a transportation system that crew can routinely operate from the Earth-moon vicinity to Mars orbit and Martian surface.

Response: Agree, but the technology path should not be locked down until we have learned lessons from cislunar operations. There are going to be significant differences between what an Earth-Moon and Earth-Mars transportation system will look like, and preordaining the Earth-Mars transportation system now, before we have a working Earth-Moon system, could be a major mistake. The key variable that must be studied is whether the Earth-Mars human system will need some form of artificial gravity. The science is far from settled as to whether astronauts can travel all the way to Mars in microgravity and be able to land and undertake surface operations after spending many months without any gravity. Further, Earth-Mars transportation may be able to utilize propulsion systems that are not suitable for cislunar space, including possibly nuclear propulsion.

TH6: Develop a transportation system that can deliver large surface elements from Earth to the Martian surface.

Response: Agree. Pre-placing key elements for human missions on the surface of Mars is key. Because of the transit times involved, emphasis should be placed on developing or acquiring large cargo transport capabilities sooner rather than later so NASA can begin the process of planning for that deployment.

TH7: Develop systems for crew to live, operate, and explore on the Martian surface to address key questions with respect to science and resources.

Response: This Objective should be modified to add "for long-term habitation and possible colonization." See our general comments about the mistake of placing "science" as the main goal for human exploration of Moon and Mars. A science-only agenda will never gain sufficient public or political support for such an expensive program.

> **TH8: Develop a system that monitors crew health and performance and provides medical care to the crew during long communication delays to Earth and in an environment that does not allow emergency evacuation nor terrestrial medical assistance.**

Response: Space medicine should be a key Objective. If humans can't survive the rigors of deep space, then we are destined to live and ultimately become extinct as a single-planet species. This Objective should be elevated and at the forefront of discussions.

> **TH9: Develop integrated human and robotic systems with inter-relationships that enable maximum science return from the lunar surface and from lunar orbit.**

Response: Agree. In the push to return humans to the Moon and push out to Mars, we must bring the necessary tools with us, and robots can provide great assistance. More work needs to be done on both autonomous and teleoperated robots. Fantastic work has been accomplished over the past two decades in robotics on a shoestring budget. The advance in space robotics has been fueled, in part, by prizes awarded by the government, such as DARPA's Grand Challenge. NASA should continue to fund and increase funding to robotic experiments and especially prizes.

> **TH10: Develop integrated human and robotic systems with inter-relationships that enable maximum science return from the Mars surface and from Mars orbit.**

Response: Agree. Teleoperated robots controlled from Mars orbit, or from one of the Martian moons, could be a key technology for advancing exploration activities on Mars. NASA should support advanced study and deployment of analog systems on Earth and on the Moon., are one possible solution. *See* Geoffrey Landis, *Teleoperation from Mars Orbit: A Proposal for Human Exploration*, NASA (2006), https://www.cast.cn/uploadfiles/2017-08/369/15021578056759962.PDF.

> **TH11: Develop systems capable of returning large cargo mass from the lunar surface to the Earth, including the capabilities necessary to meet scientific sample return objectives.**

Response: Disagree. Here again, "science" is elevated above all other pursuits. We've only used about ten percent of the Apollo samples brought back 50 years ago. *See* James E. Dunstan, *Free the Rocks!*, SPACE NEWS (July 14, 1997). The Objective does not define "large cargo mass," the destination does not need to be Earth, and the driver should not be science, but rather the building of large structures to support a commerce goal. Studies by Gerard K. O'Neill and the Space Studies Institute demonstrate that lunar regolith could be used to build large solar power satellites in Earth orbit. *See* Gerard K. O'Neill, *Space Colonies and Energy Supply to the Earth*, 190 Science Magazine 943 (Dec. 5, 1975), https://www.jstor.org/stable/1741676.

TH12: Develop systems capable of returning large cargo mass from the Martian surface to the Earth, including the capabilities necessary to meet scientific sample return objectives.

Response: Unsure and disagree. The term "large cargo mass" is again not defined. Further, as stated throughout these comments, if science is the only driver, then this endeavor will fail. We suggest that NASA either re-think or re-articulate this Objective.

B. *Lunar Infrastructure (LI) Goal*

Create Global Lunar Utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence on the lunar surface for a robust lunar economy without NASA as the sole user, while accomplishing Mars testing and science objectives.

LI1: Develop an incremental lunar power grid that is evolvable to support continuous human/robotic operation and is capable of scaling to global power utilization and industrial power levels.

Response: Agree and fully support. This should be a key Objective. "Science" can't have a veto over commercial and industry access to power to fuel lunar development and a lunar economy.

LI2: Develop Lunar surface, orbital, & Lunar to Earth communications, position, navigation and timing architecture capable of scaling to support long term science, exploration, and industrial needs.

Response: Partially agree. NASA can help set standards but should rely on industry to develop and build such systems. There is far more expertise in communications, positioning, and navigation in the private sector than at NASA. This Objective should thus be accomplished by private industry, not NASA. A further issue which needs to be sorted out early is spectrum use. NASA does not have access to sufficient spectrum to support a robust commercial lunar communications system. NASA should coordinate with NTIA, the FCC, and ultimately the ITU, to develop a framework for spectrum allocation for the Moon. We at TechFreedom have worked on spectrum issues for over a decade and are happy to contribute in this area, working with all stakeholders to develop the necessary laws and regulations to allow for robust communications capabilities, including private-sector allocation of spectrum in cislunar space.

LI3: Demonstrate autonomous construction, precision landing, surface transportation, industrial scale ISRU and Advanced Manufacturing capabilities in support of future continuous human lunar presence and a robust lunar economy.

Response: Fully agree. We especially appreciate NASA using the term "demonstrate," because that is what NASA should do, and then turn the development and deployment of such technologies to the private sector. We also appreciate that (finally) the lunar economy is mentioned. More of the Objectives should be recast in this mold, where the economy, and a continuous human lunar presence are key components, rather than science alone.

LI4: Demonstrate technologies supporting cislunar orbital/surface depots, construction and manufacturing maximizing the use of in-situ materials, and support systems needed for continuous human/robotic presence.

Response: Agree. Again, we appreciate the use of "demonstrate" here. However, it does appear that this Objective includes a level of centralized planning of lunar activity, and of a lunar economy, that NASA isn't in a position to dictate. Technology demonstrations are one thing, but presaging what depots will develop, and what manufacturing activities will occur, would be counter-productive. NASA should engage with a broad swath of industry, not just with traditional aerospace contractors, in this development/demonstration role.

C. *Mars Infrastructure (MI) Goal*

Create essential infrastructure to support initial human Mars demonstration.

MI1: Develop Mars Surface Power sufficient for the initial human Mars demonstration mission.

Response: Agree. This is a key Objective and NASA should put maximum effort into developing technologies to meet this goal.

MI2: Develop Mars surface, orbital, & Mars to Earth communications to support the initial human Mars demonstration mission.

Response: Agree, but given the expertise in communications in the private sector, NASA should rely heavily on that expertise. A further issue which needs to be sorted out early is spectrum use. NASA does not have access to sufficient spectrum to support a robust commercial lunar or Martian communications system. NASA should coordinate with NTIA, the FCC, and ultimately the ITU, to develop a framework for spectrum allocation all the way out to Mars. We at TechFreedom have worked on spectrum wars issues for over a decade and are happy to contribute in this area, working with all stakeholders to develop the necessary laws and regulations to allow for robust communications capabilities, including private-sector allocation of spectrum.

MI3: Develop and demonstrate entry, descent, and landing (EDL) systems capable of delivering crew and large cargo to the Martian surface.

Response: Agree. NASA has the most experience in area and should pursue both "development" and "demonstration" of these capabilities. NASA should nevertheless engage with industry on this issue, as at least one company (SpaceX), has already indicated plans for commercial Mars operations.

D. *Operations (OP) Goal*

Conduct human missions on the surface and around the Moon followed by missions to Mars. Using a gradual build-up approach, these missions will demonstrate technologies and operations to live and work on a planetary surface other than Earth, with a safe return to Earth at the completion of the missions.

OP1: Conduct human research and technology demonstrations on the surface of the Earth, low Earth orbit platforms, cislunar platforms, and on the surface of the moon, to evaluate the effects of extended mission durations on system performance, reduce risk, and shorten the timeframe for system testing and readiness prior to the first human mission to Mars.

Response: Agree. This step-by-step approach will allow for early identification of issues and problems related to the technology path. NASA must remain flexible, however, if black swan technologies emerge that could shorten the technology path.

OP-2: Optimize operations, training and interaction between crew, the support team on Earth, orbital support and a Martian surface team considering communication delays, autonomy level, and time required for an early return to the Earth.

Response: Agree. This is a traditional role for NASA which it can then commercialize for operations in cislunar and Earth-Mars space. This is a proper government function that is not easily replicated in the commercial space industry.

OP3: Characterize accessible lunar resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable ISRU on successive missions.

Response: Agree. Again, this is a proper role for NASA, which can build upon the decades of fine work done by the Lunar and Planetary Institute. LPI, https://www.lpi.usra.edu/ (last visited June 2, 2022). Additional efforts should be made to commercialize the outputs of such studies as soon as practicable.

OP4: Establish command, control and coordination and processes that will support expanding human missions at the Moon and Mars.

Response: Agree. Another traditional role for NASA. Eventually, NASA should consider offloading some of the outputs of these efforts to another agency to more closely mirror the U.S. air traffic control system.

OP5: Operate surface mobility systems using extra-vehicular activity (EVA), suits, tools and vehicles.

Response: Disagree. It is unclear what NASA's role should be in surface mobility systems. It is quite possible that commercial companies could develop and operate such systems more efficiently. NASA is already supporting commercial robotic systems on the Moon. NASA should revisit this Objective and rework or reword it to make clearer the roles of NASA and its commercial partners concerning surface operations. The worst possible result would be confusion for investors, who might read this Objective as a moratorium on commercial surface mobility system operations, or of NASA wishing to compete with the private sector.

OP6: Evaluate, understand, and mitigate the impacts on crew health and performance of a long deep space orbital mission, followed by partial gravity surface operations on the Moon.

Response: Agree. This is a proper role for NASA.

OP7: Validate readiness of systems and operations to support crew health and performance on the first human mission to Mars.

Response: Partially agree. It is unclear if this Objective would extend to a purely private human mission to the Moon. NASA does not have statutory authority to regulate such missions by "validat[ing] readiness" and should not be able to veto private missions that are otherwise approved by a proper regulatory agency. This is a complicated issue under international treaty as well as domestic U.S. space law. For more information on this issue, *see Light Touch to Space Regulation under New House Bill*, TECHFREEDOM (June 8, 2017), https://techfreedom.org/light-touch-to-space-regulation-under-new-house/.

OP8: Demonstrate the capability to find, service, upgrade, or utilize instruments and equipment from robotic landers or previous human missions on the surface of the Moon and Mars.

Response: Partially agree. NASA certainly can have a role in servicing its instruments and equipment, but this Objective needs to be modified to make clear that NASA doesn't gain any legal rights to third-party equipment on the Moon and Mars. Further, the role of servicing equipment historically is one of the first roles to be commercialized, and NASA should do everything possible to encourage such outsourcing of service functions to the private sector.

OP9: Demonstrate the capability of integrated robotic systems to support and augment the work of crewmembers on the lunar surface, and in orbit around the Moon.

Response: Agree. NASA has traditionally supported such work and should continue to do so by demonstrating advancing capabilities in this area. Nevertheless, much of the cutting-edge expertise in robotics systems lives outside of NASA, and this Objective should not be viewed as NASA attempting to monopolize human/robot interactions, or somehow attempt to bring such expertise in-house to the detriment of the commercial sector.

OP10: Demonstrate the capability to remotely operate robotic systems that are used to support crew members on the Lunar or Martian surface, from the Earth or from orbiting platforms.

Response: Agree. NASA has supported work in teleoperations of robotic systems and should continue to do so. Again, much of this experience in this area resides outside of NASA, and this Objective should be clarified to indicate that NASA will tap this expertise rather than try and recreate that expertise in-house.

OP11: Demonstrate the capability to use commodities produced from planetary surface or in-space resources to reduce the mass required to be transported from Earth.

Response: Don't understand. This Objective is unclear and should be reworded. We agree if this is meant to explain traditional concepts of *in situ* utilization to reduce uplift mass from Earth, but we are confused as to why the term "commodities" is used and what that means.

E. *Exploration Science (ES) Goal*

Conduct science on the Moon and in cislunar space, using integrated human and robotic methods and advanced techniques, to address high priority U.S. scientific questions about the Moon and to demonstrate methods for future science by astronauts beyond the Earth-Moon system.

ES1: Conduct human field geology on the surface and select high priority sample specimens for return to Earth.

Response: We are very concerned that the only place "priority" is used throughout the 50 Objectives is the "Science Objectives" section of this document. As emphasized in our general comments, if science is the only "priority" of the Moon/Mars program, then the program will never garner either public or political support to move much beyond the planning stage. It will be a repeat of post-Apollo, SEI, and every other attempt to return humans to the Moon. Further, given NASA's hoarding of the Apollo samples (only approximately ten percent of which have been used), TechFreedom questions whether sample return will truly be done for scientific reasons, or whether NASA merely wishes to increase its cache of lunar materials. Further, NASA needs to change its policy regarding access to lunar samples to allow for greater use of the samples for engineering experimentation. See James E. Dunstan, *Free the Rocks!*, SPACE

NEWS (July 14, 1997). If, however, the science aspects of this endeavor are properly balanced with economic development, engineering experimentation, and other factors, then TechFreedom agrees that NASA should prioritize sample return specimens.

ES2: Demonstrate advanced techniques and tools to enable Earth-based scientists to remotely guide astronaut surface activities.

Response: Agree. "Demonstration" in this context is a proper role for NASA.

ES3: Enable in-situ research by delivering science instruments to the lunar surface at various locations and returning high priority samples to Earth.

Response: Agree, with the caveat listed above about concerns about the use of the term "priority." *In situ* resource utilization is absolutely key to sustaining a human presence on the Moon, and in this instance, those activities should be prioritized. *See* GERARD K. O'NEILL, THE HIGH FRONTIER: HUMAN COLONIES IN SPACE (1989).

ES4: Survey sites, conduct in-situ measurements, and identify/stockpile samples for later astronaut evaluation or retrieval.

Response: Agree. This is a proper role for NASA exploration.

ES5: Demonstrate retrieval of frozen volatile deep core samples from permanently shadowed regions on the Moon.

Response: Agree. This should be the top priority within this group of Objectives because of the scientific value of such volatiles. We would also suggest that a separate Objective be added to the Lunar Infrastructure Goal because of the supreme importance volatiles will have on the ability to sustain a continued human presence on the Moon. Having it there, as well as here, makes clear that lunar volatiles are a key item in the Objectives. Addressing volatiles here, solely within the context of "science," downplays the importance of this resource for future human habitation of the Moon.

ES6: Establish methods and systems to allow a large number of science instruments to conduct planetwide long-term measurements.

Response: Agree, but within the context of the overall science goals, and especially given the discussion of volatiles above, this Objective is far less important than others.

ES7: Establish a scientific laboratory at the lunar South Pole to conduct high value lunar surface science.

Response: Disagree. The trouble is with the context in which this is presented. This is the only place in the 50 Objectives where a human base at a lunar pole is discussed. Are we to glean from this that the sole goal of a human polar base will be scientific research? Are we to assume that NASA wishes to treat the Moon like Antarctica, where access to resources for non-scientific endeavors are basically forbidden? Are scientists and engineers not going to use such a base to create power (*e.g.,* at a Peak of Eternal Light), or mine volatiles for utilization in sustaining humans? We again object to the science focus of these Objectives, and particularly this Objective that is so critical to sustaining a human presence on the Moon.

ES8: Utilize Mars Sample Return (MSR) mission results to optimize human-led science sampling campaigns on Mars, sample return to Earth and characterize landing sites.

Response: Agree. Such precursor exploratory missions are well within the traditional role of NASA.

F. *Lunar/Planetary Science (LPS) Goal*

Address those high priority planetary science questions which are best accomplished by on-site human explorers on the Moon and Mars, aided by robotic systems.

LPS1: Conduct in-situ studies of planetary processes (Differentiation, Impact, Volatiles, Volcanism and Tectonism) to understand planet formation.

Response: Agree but object to use of the term "high priority" here and not as it relates to other non-science Objectives.

LPS2: Collect fundamental data to understand volatile cycles (comet impacts, solar wind hydrogen, primordial, permanently shadowed regions), including types/extent of chemicals present.

Response: Agree. We believe that this science Objective is the most important, as understanding more about lunar volatiles is a key variable in determining how to sustain a human presence on the Moon.

LPS3: Determine impact history of the Earth-Moon system.

Response: Disagree slightly. NASA already has done substantial work in mapping out the impact history of the Earth-Moon system based on orbital observations. It is unclear why this is an Objective and how it fits into a human return to the Moon architecture. Unless NASA can articulate why we need "boots on the ground" on the lunar surface to better understand impact history, we believe that this Objective should be dropped.

LPS4: Collect samples over a long traverse/duration in the South Pole Aitken Basin and deliver the samples to astronauts for return to Earth.

Response: Agree. Long traverses will be necessary to collect samples from a wide variety of areas of the South Pole Aitken Basin. The more differentiation in samples that can be achieved, the better those samples will inform our knowledge of the Moon, and more importantly, how we can utilize lunar resources for human sustainability on the Moon.

G. *Heliophysics Science (HS) Goal*

Address those high priority heliophysics science and space weather questions which are best accomplished using a combination of human explorers and robotic systems on the Moon and in cislunar space.

HS1: Understand space weather phenomena to enable improved prediction of the dynamic space environment for deep space exploration.

Response: We agree that space weather is important. The undersigned has made presentations about the legal impact of space weather on commercial human spaceflight at Space Weather Week, April 25-28, 2006, in Boulder, Colorado ("Commercial Passenger Space Flights: Assessing the Space Weather and Environment Needs of Flight Operators"), and the 2007 Space Weather Enterprise Forum, April 4-7, 2007, Washington, DC ("The Role of Space Weather in an 'Informed Consent Liability Regime' for Commercial Space Flight Participants"). What is unclear from this objective, however, is how the Artemis program is necessary to advance the knowledge of space weather. Instead, it appears that heliophysics in this instance is merely a passenger, if not a stowaway, on this program. Unless NASA can articulate why increased knowledge of space weather is on the critical path of returning humans to the Moon and on to Mars, this Objective should be deleted.

HS2: Remotely observe the Sun and Geospace and conduct in-situ measurements in the deep magnetotail and pristine solar wind, to understand the dynamics of the connected Sun-Earth system.

Response: Again, this is a "nice to have" Objective, but there is inadequate articulation of why this goal is on the critical path of the Artemis program. Yes, heliophysics experiments can ride along with humans as they return to the Moon and on to Mars, but we deeply question how these three Objectives make the top 50.

HS3: Discover and characterize fundamental plasma processes including dust-plasma interactions, using the cis-lunar environment as a laboratory.

Response: Better articulation of this Objective is required. It may be that we can only gain this knowledge through the Artemis program, but as stated, this appears to just be tagging along with the humans as they return to the Moon.

H. *Biological and Physics Science (BPS) Goal*

Understand fundamental biological effects when organisms are present in fractional-gravity and deep-space environments, to gain new scientific understanding and information to guide system development.

BPS1: Understand the fundamental biological effects of short and long duration exposure to the lunar environment on human physiology and disease.

Response: Agree. This is a key goal. If we are to become a multi-planet species, we must find out whether humans can survive in these different environments. Sixty years of humans in Earth orbit, including long-duration human stays on Mir and ISS, have provided a deep data set on living in microgravity, with less than encouraging results in terms of the human body's ability to survive long-term in that environment. We have roughly 300 human hours (12.5 human days) on the lunar surface from the Apollo missions (11-12, 14-17, with the longest duration of surface time being 44 hours on Apollo 17), with minimal on-site monitoring of the impact of one-sixth gravity on the human body. We must accumulate data on many months, if not years, of human activity on the lunar surface and its impact on human physiology. We question, therefore, why these BPS Goals are listed behind almost all the other science goals of the program.

BPS2: Understand the fundamental biological effects of short and long duration exposure to the lunar environment on plants used to provide crew nutrition/behavioral health.

Response: Agree. We will never become a true spacefaring species if we cannot produce food *in situ.* Emphasis should be placed on experiments that look toward basic farming techniques and identifying plant species that can be grown in space, on the Moon, and on Mars to feed a continued human presence.

BPS3: Understand the fundamental biological effects of short and long duration exposure to the lunar environment on the survival and adaptation of microbes associated with the crew, plants, and the built environment.

Response: Agree. NASA has a long history of studying closed-loop environmental systems, which has led to an understanding of both the robustness and fragility of Earth environmental processes. Experiments such as Biosphere have demonstrated how difficult it can be to build and maintain environmental systems that can support long-term human life. The Artemis program can push this understanding further and help develop next-generation engineering solutions to keeping humans alive on the Moon and then Mars.

BPS4: Understand transient or permanent physiological changes on several generations of organisms.

Response: Agree. The Apollo missions were designed, by necessity, to be short-term sorties. A robust return to the Moon campaign must study biology over several generations of organisms. This is especially true if we want to provide a safe living environment and food supplies for long duration missions to Mars and eventual continual habitation and colonization.

I. *Astrophysics Science (AS) Goal*

Preserve the far side of the Moon as a "radio-free zone" for future radio astronomy experiments.

AS1: Monitor the radiofrequency environment on the lunar far side to enable future far side radioastronomy activities.

Response: Agree, partially. The undersigned author has long been a strong advocate for maintaining and protecting spectrum usage for space applications. *See, e.g., James E. Dunstan, Earth*

To Space: I Can't Hear You; Selling Off Our Future To The Highest Bidder, Space Manufacturing 11 (1997); TechFreedom, Comments on the Petition for Rulemaking to Permit MVDDS Use of the 12.2-12.7 GHz Band for Two-Way Mobile Broadband Service, RM—11768 (Oct. 8, 2020), https://techfreedom.org/wp-content/uploads/2020/10/TF-Comments-12-GHz-MVDDS.pdf. The lunar far side provides a unique platform for radio astronomy, being shielded from the RF noise emanating from Earth. Having said that, lunar far side operations, including L-2 communications satellites, will need access to spectrum to support cislunar communications. Declaring the entire far side of the Moon as a "radio-free zone" simply is not possible. NASA, in conjunction with the FCC, NTIA, and the State Department, should work both domestically and at the ITU to preserve key frequencies for radio astronomy uses, while still ensuring that human and robotic operations, both scientific and commercial, can be supported with robust communications. It is fitting that this is the 50th Objective, as it brings full circle this analysis, and allows us to drive home our paramount concern one more time—science cannot have a veto over commerce and the economic development of the cislunar region. Commerce and science must work together symbiotically if the Artemis program has any hope of ultimate success in returning humans to the Moon and moving out to Mars.

V. Conclusion

A human return to the Moon, and a push to Mars, is long overdue. To date, NASA has not been able to dial up the right mix of goals and objectives that can garner broad public and political support for such an endeavor. Unfortunately, the 50 Objectives NASA has articulated is a retread of insular planning and in house desires that ignore the real world outside NASA headquarters and the major NASA centers. Without commerce as a central pillar, this effort will fail. Without tapping into the capabilities and cost reductions achievable by the private sector, delays and cost overruns will consume this effort. We hope that NASA soberly assess whether its current planning pathway is sustainable. We believe it is not. If NASA truly wants a human breakout into deep space, it must think differently, and look outside the agency to the revolution that is occurring in commercial space. Find out what they are doing right and apply that to its goals and objectives. We truly believe we can open a thriving cislunar economy in the next decade, if NASA is willing to tap into the best that is America—its innovation and entrepreneurship.

Respectfully submitted,

___________/s/_____________

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