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WHY COMMERCIAL SPACE SHOULD LEAD THE U.S. RETURN TO THE MOON

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EXECUTIVE SUMMARY

NASA's return-humans-to-the-moon program is a failure. Conceived as a modernized version of the Apollo program of 50 years ago, it is based on a massive launch vehicle (SLS), an adaptation of the Apollo capsule, and "proven" components from the failed Space Shuttle program—refurbished engines and modified solid rocket boosters. All are being delivered under sole-source, cost-plus contracts and all are years behind schedule and tens of billions over budget. *And none of the most-expensive components are re-usable.* The program has ignored the advantages and cost savings of reusable launch systems.

A 2021 review by the NASA inspector general projected that the accumulated cost by 2025 would be \$93 billion. Including the six planned SLS missions through 2031, the average cost of each would be ~\$30 billion for only a handful of crew each.

This vision paper calls for the current SLS program to be canceled and replaced by a new approach that relies on state-of-the-art reusable launch vehicles, makes use of multiple launches on low-cost reusable boosters rather than a single giant vehicle, and would likely enable more moon landings sooner than is realistic via SLS and its related systems. The new approach could be funded by savings from the cancellation of most or all the SLS components. Projected savings would be ~\$4.25 billion per year if the Gateway lunar satellite remains in the program or ~\$5.25 billion per year if Gateway is also canceled.

This vision paper calls for re-thinking the case for getting humans to the moon. As with Apollo's premise of beating the Soviet Union to the Moon, today there is considerable

support in the White House and Congress to beat China to the Moon. If doing this is seen as essential, replacing NASA's hugely costly, chronically late approach is vital.

Another historical reason for the SLS program was to maintain a large workforce at NASA centers in key states as well as large workforces at major aerospace contractor facilities. But given the massive cost overruns and missed deadlines in the SLS program, this rationale should no longer drive space policy. NASA would continue to oversee and foster space science and technology development, but it would not be the entity developing the launch vehicles. It would be far better to deploy those workforces to things that the commercial sector cannot do.

The keys to a cost-effective moon landing program are competition and reusability. NASA should adapt the public-private partnership approach that it has used successfully for cargo and crew delivery to and from the International Space Station. There should be no more cost-plus contracts. Potential partly or fully reusable launch vehicles include Blue Origin's New Glenn, ULA's Vulcan, and SpaceX's Falcon 9, Falcon Heavy, and likely soon, Starship. Instead of relying on one giant, expensive, and rarely flown launch vehicle, each moon journey would use multiple launches of fuel and equipment to be assembled in orbit for the trip to and from the Moon. Potential landers include the already-planned Blue Moon and Starship HLS. An alternative to NASA's troubled Orion could be a version of the SpaceX Crew Dragon. But the alternative architectures needed to expedite a return to the Moon will require acceptance of risk at the same level as Apollo, and that the Chinese accept today.

NASA needs to bite the bullet and end its use of obsolete, non-reusable launch vehicles and sole-source, cost-plus contracts. It should shift to state-of-the-art reusable spacecraft and public-private partnerships like those now transporting cargo and people between Earth and the International Space Station. The estimated annual savings from terminating the current program are as follows:

SLS launch vehicle	\$2.0 billion
Orion capsule	\$1.4 billion
Upper stage (EUS)	\$0.6 billion
New launch tower	\$0.25 billion
Gateway	\$1.0 billion
Total Annual Savings:	\$5.25 billion

The more than \$5 billion annual savings from terminating the current SLS program should be ample to fund a revamped program that accomplishes the goal, shared by the White House and Congress, of returning humans to the Moon before the Chinese government does.

The White House draft NASA budget, released in early May 2025, calls for terminating the SLS program after the second and third SLS launches. That plan would terminate SLS, Orion, upper stage, new launch tower, and Gateway. This would save tens of billions in future SLS missions, but would unfortunately delay the \$5 billion per year cost savings needed to finance the replacement commercial space alternative. It would also potentially result in an SLS program dragged out by a demoralized staff, rather than allowing the staff to transition to something more productive. A better approach is to end the program now.

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NOTE: Only publicly available information was used to produce this vision paper, and there were no communications with any of the companies discussed in it.

PART 1

FINANCIAL CHALLENGES WITH SLS/ORION

NASA's current goal of returning Americans to the Moon is called Artemis (sister of the god Apollo in Greek mythology), with the aspiration to land Americans on it by the end of the current decade. The Space Launch System—NASA's new heavy-lift rocket—and the Orion capsule, a scaled-up version of the Apollo capsule that took Americans to the Moon in the late 1960s and early 1970s, have been declared essential to meeting that goal. But this program has faced many challenges, costing tens of billions of dollars over the past 14 years since the programs were initiated.¹

SLS/Orion were created by the NASA Authorization Act of 2010, and the concept was bipartisan; the primary instigators of the programs were Senators Kay Bailey Hutchison (R-Texas) and Bill Nelson (D-Florida), the latter of whom later became President Biden's NASA administrator after losing his Senate seat. The legislation did not define much in the way of requirements, other than the SLS had to initially deliver between 70 and 100 tons to orbit, with eventual capability of 130 tons.²

¹ The capsule in the Constellation architecture, which the Obama administration canceled in 2009, was named "Orion," but when the replacement program was initiated in 2010, the legislation called it a "Multi-Purpose Crew Vehicle" (MPCV). It was later renamed "Orion," like its canceled predecessor.

² It was not specified in the legislation whether or not this was imperial or metric tons, but the spelling would imply the former (2000 lbm) rather than 1000 kg (~2200 lbm). However, later, in briefings to Congress, NASA would use metric units. Given the lack of design reference mission for it, it didn't really matter.

1.1

RUNAWAY COSTS FOR SLS/ORION

Neither SLS nor Orion has ever had a specific, performance-based Design Reference Mission. As a result, during system analysis it became apparent that the SLS was not capable of getting Orion all the way to the Moon on its own and would need some intermediate destination.³ In 2012, the Obama administration changed the focus for NASA human spaceflight from going to the Moon to doing an asteroid-retrieval mission. Part of that concept was a cislunar habitable space station (though not necessarily permanently crewed), initially called the Deep Space Gateway, depicted in Figure 1.⁴ In 2018, with a policy shift back to the Moon in the Trump administration, it was renamed the Lunar Orbital Platform-Gateway (LOP-G). It has since become known simply as “Gateway.” It is to be placed in an unusual cislunar orbit called a Near-Rectilinear Halo Orbit (NRHO), depicted in Figure 2.⁵ It is a key part of the Artemis architecture because the selected orbit is accessible both by SLS and from the lunar surface. Like the ISS, Gateway is an international project, which (as with the Orion service module) makes it more difficult, politically, to cancel. Critics of the concept view it as unnecessary for human expeditions beyond Earth orbit (e.g., Mars Society head Robert Zubrin has called it a pointless “tollbooth”).⁶ Some even question whether we should be focusing on the Moon instead of Mars. Several billion dollars have been spent on Gateway to date, and the FY2025 NASA budget for it is over \$800M.

“

...the SLS was not capable of getting Orion all the way to the Moon on its own and would need some intermediate destination.

”

³ Ryan Whitley and Roland Martinez, “Options for Staging Orbits in Cis-Lunar Space” NASA Johnson Space Center, 21 Oct 2015, 8, Table 6.

<https://ntrs.nasa.gov/api/citations/20150019648/downloads/20150019648.pdf>

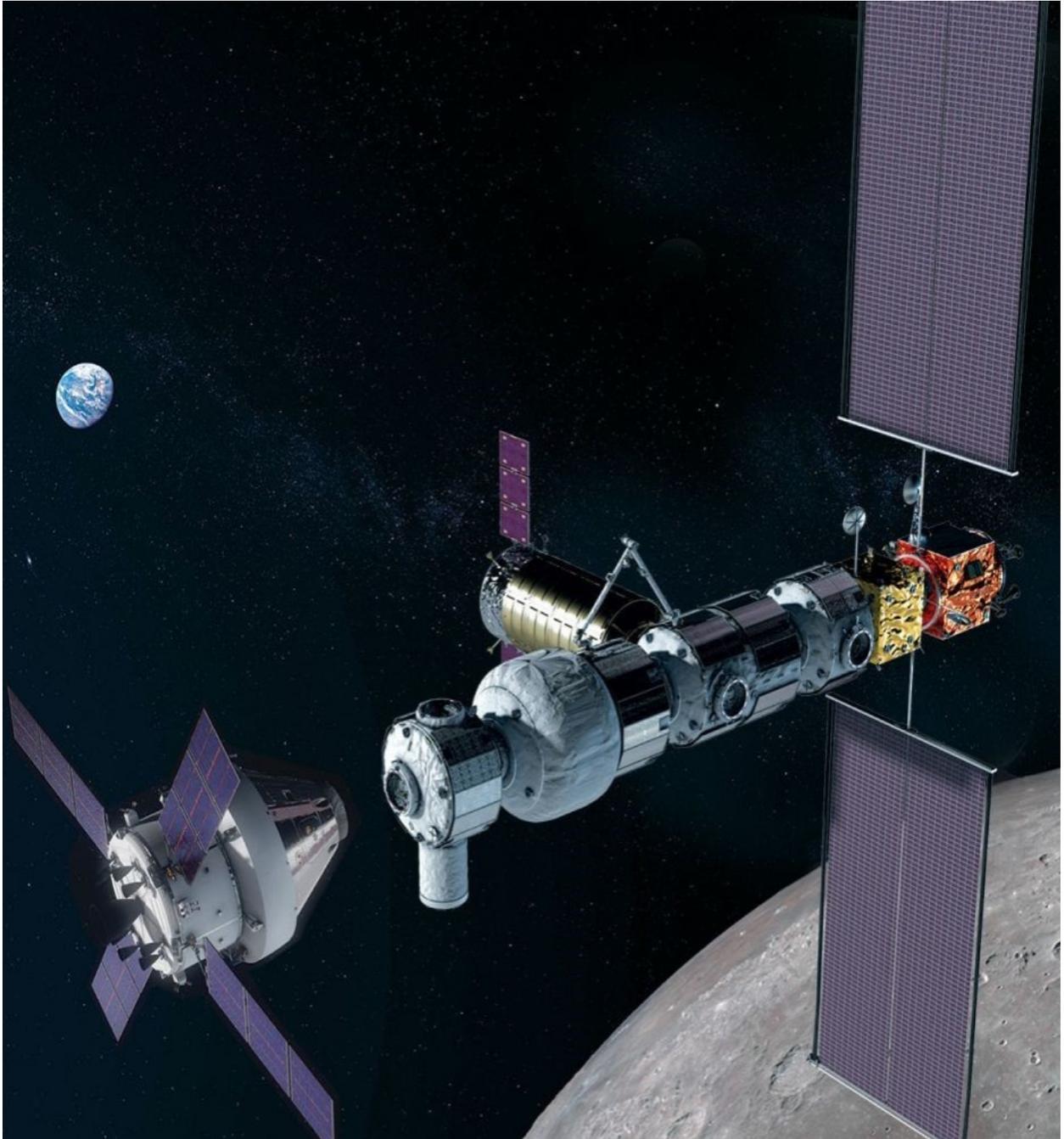
⁴ “Cislunar” literally means “between Earth and the Moon,” but it has become an industry shorthand for the region containing both bodies. There are an infinite number of cislunar orbits, with a range of altitudes from both Earth and the Moon.

⁵ Nathan Parrish et al. (5 January 2020), “Near Rectilinear Halo Orbit Determination with Simulated DSN Observations” (PDF), AIAA Scitech 2020 Forum, American Institute of Aeronautics and Astronautics. doi:10.2514/6.2020-1700. ISBN 978-1-62410-595-1.

⁶ Robert Zubrin, “Cancel the Lunar-Orbit Tollbooth,” *nationalreview.com*, *The National Review*, 13 Sep. 2018. <https://www.nationalreview.com/2018/09/nasa-lunar-orbiting-platform-gateway-should-be-canceled/> (20 May 2025).

Figure 1 shows Gateway, which is the intermediate destination for Orion.

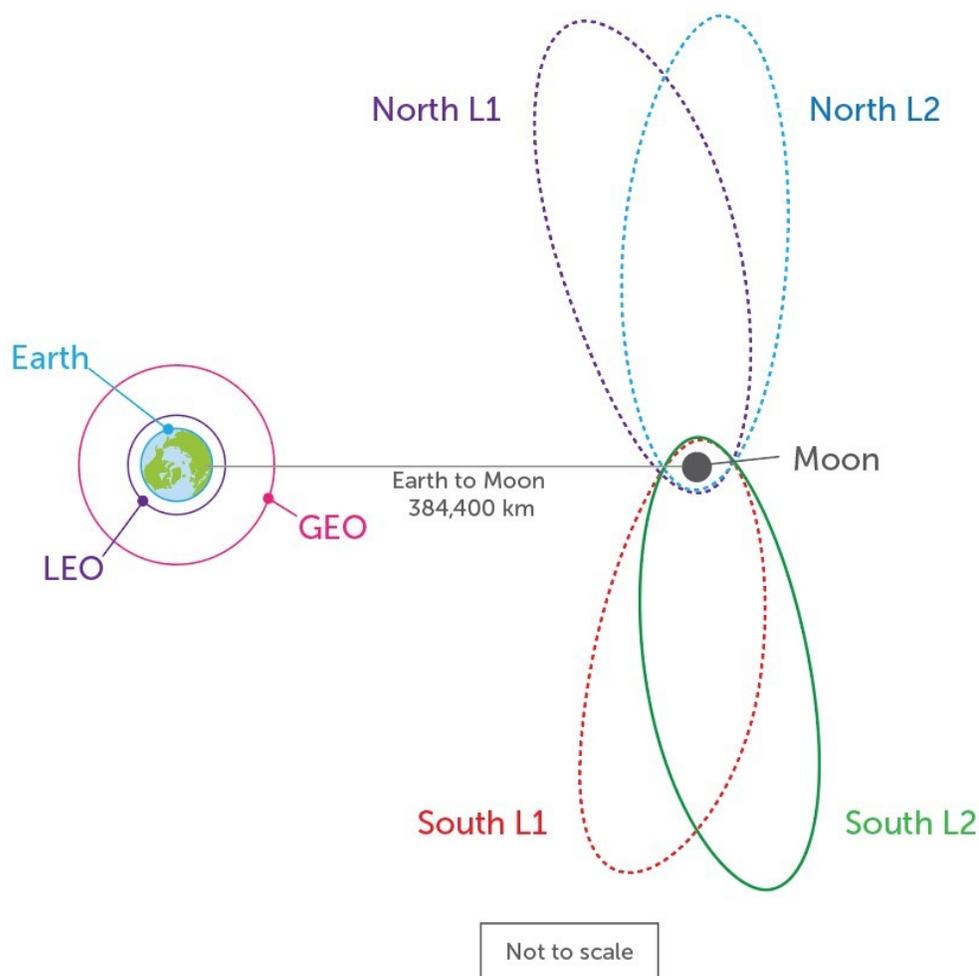
FIGURE 1: GATEWAY



Source: NASA

Figure 2 shows a seven-day orbital period for which NRHO offers weekly access to the Moon.

FIGURE 2: NEAR-RECTILINEAR HALO ORBIT



Note: In the figure, the South L2 oval is solid because it is more likely to be chosen than the other three options.
Source: Maxar <https://blog.maxar.com/space-infrastructure/2019/what-is-cislunar-space-and-a-near-rectilinear-halo-orbit>

The costs of the overall program continue to grow. According to an audit in late 2021 by NASA’s Office of Inspector General (OIG), total costs for Artemis were expected to reach \$93 billion by 2025.⁷ This included new rounds of NASA Human Landing System (HLS) contracts to SpaceX and other contractors in response to congressional concerns about lack of redundancy and competition for the mission-critical element. In March 2022, NASA

⁷ “NASA’s Management of the Artemis Missions,” NASA Office of Inspector General, 15 Nov 2021. [oig.nasa.gov/wp-content/uploads/2024/02/IG-22-003.pdf](https://www.oig.nasa.gov/wp-content/uploads/2024/02/IG-22-003.pdf)

Inspector General Paul Martin told Congress that “...the operational cost alone for a single Artemis launch—for just the rocket, the Orion spacecraft, and ground systems—will total \$4.1 [billion],” a cost that he declared “unsustainable.”⁸ That cost did not include annual fixed costs for the program, or amortization of the development costs of over a decade. Note also that the marginal cost of a single flight of SLS is almost half the total development cost to date (~\$10 billion) of SpaceX’s Superheavy/Starship, which, while still in flight testing, has flown several times.⁹ That \$93 billion number, which did include fixed and amortized costs, meant that if there is ultimately only one flight of the architecture (the total number of flights as of this writing), it would have cost over \$90 billion. Including the billions that would be spent in subsequent years, the first six planned Artemis missions through 2031—only five of which would be crewed, and only four of which would land and return a very small number of humans—will average around \$23 billion each to deliver a handful of people to the lunar surface and return.¹⁰

SLS isn’t entirely Shuttle derived; initially, in the concept called Block 1A, its upper stage is the same upper stage as that of the United Launch Alliance (ULA) Delta IV (which used cryogenic LOX/H₂), but only for the first three flights. After that, the plan is to upgrade it to Block 1B with a new cryogenic stage, called the Exploration Upper Stage (EUS). This stage will increase its payload capability, which is anticipated to be introduced on the fourth flight. Per congressional dictate, the initial payload capability is 70 tons to Low Earth Orbit (LEO), with Block 1B projected to increase to 105 tons with the new upper stage.¹¹ But instead of using state-of-the-art components, this upgrade of obsolete hardware generates increased costs.

⁸ Eric Berger, “Finally, we know production costs for SLS and Orion, and they’re wild,” *Ars Technica*, 1 Mar 2022. [www.arstechnica.com/science/2022/03/nasa-inspector-general-says-sls-costs-are-unsustainable/](https://arstechnica.com/science/2022/03/nasa-inspector-general-says-sls-costs-are-unsustainable/)

⁹ Stephen Clark, “Rocket Report: A new estimate of Starship costs; Japan launches spy satellite,” *Ars Technica*, 19 Jan 2024, <https://arstechnica.com/space/2024/01/rocket-report-a-new-estimate-of-starship-costs-japan-launches-spy-satellite/>

¹⁰ This is based on the estimated \$93 billion through 2025, and assumed continuing annual fixed annual cost, based on history, of \$5 billion per year through 2031 of \$25 billion, plus five Artemis missions at \$4 billion each, for a total of about \$140 billion, divided by six total flights.

¹¹ The program plan includes a Block 2, which would further increase capability by, among other things, replacing the SRBs with liquid boosters, either expendable or recoverable, but this has never been defined sufficiently to evaluate how long it would take to develop, or how much it would cost to either develop or operate.

1.2 RUNAWAY COSTS FOR THE LAUNCH PLATFORM

Part of those costs is the Mobile Launch Platforms (MLP), based on previous Saturn and Shuttle use, needed to move the stacked SLS/Orion from the Vehicle Assembly Building (VAB) at Cape Canaveral to its launch pad (see Figure 3). In March 2020 the OIG issued a report on cost overruns on both platforms. ML-1 had been modified from work done on Constellation, but a combination of poorly understood requirements early on and poor contractor performance (on yet another cost-plus contract) had more than doubled its costs from an original 2014 estimate of ~\$300 million, to almost \$700 million. These high costs are for a platform that would only be used for three launches (adding an additional \$200M+ per launch), because SLS Block 1B (planned to fly after that), due to its additional height from the EUS, needs a taller platform, called ML-2. As of 2020, the estimate for that was about \$500 million, but the OIG considered both schedule and cost high risk due to contract structure and poor contractor coordination.¹²

Figure 3 shows the Mobile Launch Platform, which is another relic of the Shuttle program.

FIGURE 3: THE MOBILE LAUNCH PLATFORM (ML-1)



Source: NASA <https://spacenews.com/report-finds-delays-and-cost-overruns-in-sls-mobile-launch-platform-development/>

¹² "Audit of NASA's Development of Its Mobile Launchers," NASA Office of Inspector General, 17 Mar 2020. <https://oig.nasa.gov/wp-content/uploads/2024/02/IG-20-013.pdf>

In August 2024, the OIG issued a follow-on report on ML-2, in which it projected that the total cost of the hardware could reach almost three billion dollars by the time it was delivered to NASA by the contractor Bechtel, or almost six times the estimate from four years earlier. The report criticized NASA’s cost management on the cost-plus contract and recommended converting it to fixed-price, but NASA decided to keep it as it was due to concern over schedule.¹³

It’s worth noting that the Mobile Launch Platform is basically a steel structure with umbilicals on a bed with engines and tracks to slowly move the stack to the pad. As renowned space reporter Eric Berger of *Ars Technica* noted, “...the estimated cost of the tower, which is a little bit taller than the length of a US football field with its end zones, is now \$2.7 billion.”¹⁴ In addition, though it is required for Artemis IV, planned at that time for 2028, the chance that it would hit that schedule was (and is) close to zero. Table 1 compares the size and cost of ML-2 and SpaceX’s “Mechazilla” that launches and captures its Starship boosters.

TABLE 1: COST COMPARISONS BETWEEN BECHTEL TOWER AND MECHAZILLA

Building	Overall Cost	Construction Timeframe	Cost per Foot
Bechtel Tower	\$2.7 Billion	13 Years	\$7 Million/ft
Mechazilla	\$200 Million	1 Year	\$0.4 Million/ft

1.3

RUNAWAY COSTS DUE TO COST-PLUS CONTRACTING

The most important requirement of the NASA Authorization Act of 2010 was that it utilize:

*...existing contracts, investments, workforce, industrial base, and capabilities from the Space Shuttle and Orion and Ares 1 projects [from Constellation], including...Space Shuttle-derived components and Ares 1 components that use existing United States propulsion systems, including liquid fuel engines, external tank or tank-related capability, and solid rocket motor engines; and associated testing facilities, either in being or under construction as of the date of enactment of this Act.*¹⁵

¹³ “NASA’s Management of the Mobile Launcher Project,” NASA Office of Inspector General, 27 Aug 2024. <https://oig.nasa.gov/wp-content/uploads/2024/08/ig-24-016.pdf>

¹⁴ Eric Berger, “NASA has to be trolling with the latest cost estimate of its SLS launch tower,” *Ars Technica*, 27 Aug 2024 <https://arstechnica.com/space/2024/08/nasas-second-large-launch-tower-has-gotten-stupidly-expensive/>

¹⁵ S.3729 - National Aeronautics and Space Administration Authorization Act of 2010, 111th Congress (2009-2010) www.congress.gov/bill/111th-congress/senate-bill/3729/text

While NASA's intent was to save money through using the existing Shuttle workforce and contracts, sole sourcing to the existing Constellation contractors (primarily Boeing and Northrop Grumman for the SLS and Lockheed-Martin for the Orion) is responsible for much of the burgeoning costs. This well-intended strategy has instead led to exorbitant spending, costly delays, and in some cases, scrapped plans. Much of the cost increase stems from forgoing competitive bidding and using cost-plus contracts rather than fixed-fee nature.

COST-PLUS CONTRACTING

In a "cost-plus" contract, the contractor bills the customer for labor and materials, which are audited by the government, and they are reimbursed with some percentage of fee on top for profit. In contrast, a "fixed price" contract is one in which the bidder performs the work for a fixed price, either making profit or losing money, depending on how well they can deliver within that price. Cost-plus contracts are often used for highly technical, high-risk projects, but contractors can abuse them, by using the change order process to secure additional work that should have been included in the original scope. This increases their profit. Moreover, projects can go wildly over-budget, and have done so, as the purse is seemingly unlimited. It is worth noting that in fact, there should have been nothing high risk about building a rocket and capsule using 1970s technology.

1.4

THE CONSEQUENCES OF COST OVERRUNS

The first SLS/Orion mission had been originally scheduled for 2016. Now designated Artemis I, the schedule had continually slipped for over half a decade, but eventually launched in November 2022. The Orion capsule splashed down in the Atlantic half a century to the day after the last lunar landing of Apollo 17. The mission was largely successful, except there was more damage to the heat shield than anticipated, and there were problems with the telemetry data needed for mission control and evaluation. This has resulted in a slip of planned schedule for Artemis II, the first crewed circumnavigation of the Moon with Orion, from September 2025 to April 2026, until the problem can be better understood.



From September 2021 to September 2023 the company was issued 71 Corrective Action Requests (CARs) on deficiencies in quality, an unusually high number for a program of the supposed maturity of this one, and it had been unresponsive to them.



Beyond that, Boeing was having problems at its Michoud facility with quality control on construction of the SLS core, with a dome of an LOX tank suffering from poor welds, and there was indecision on whether or not it could be used. From September 2021 to September 2023 the company was issued 71 Corrective Action Requests (CARs) on deficiencies in quality, an unusually high number for a program of the supposed maturity of this one, and it had been unresponsive to them.¹⁶ It was supposedly due to an insufficient number of trained and experienced workers at the company (which seems strange, given that a primary reason for the program was to access the experienced Shuttle workforce).

NASA seemed to have realized, per statements it was making to the Government Accountability Office, that affordability of the SLS was becoming a problem that was putting the program at risk politically.¹⁷ In July 2022, the agency put out a press release stating that it was going to move from the current contract model, in which NASA procured hardware from the contractors, to a different model in which it would purchase flight services from a new commercial entity named Deep Space Transport LLC (DST), which would be a joint venture of the two major contractors Boeing, which built the core stage, and Northrop Grumman, which provided the solid rocket boosters (SRBs).¹⁸ It put out a pre-solicitation notice of its intent to acquire such services, which it called an “Exploration

¹⁶ Note that this was at a time when Boeing was deservedly under fire for quality issues not just with Starliner, but in its aviation business as well, so it was not in any way surprising or “out of family.”

¹⁷ “Space Launch System: Cost Transparency Needed to Monitor Program Affordability,” U.S. Government Accountability Office, gao.gov, 7 Sep 2023. [https://www.gao.gov/products/gao-23-105609#:~:text=Senior%20NASA%20officials%20told%20GAO,saving%20strategies%20for%20future%20missions.\(7 May 2025\).](https://www.gao.gov/products/gao-23-105609#:~:text=Senior%20NASA%20officials%20told%20GAO,saving%20strategies%20for%20future%20missions.(7%20May%202025).)

¹⁸ “NASA Prepares for Space Launch System Rocket Services Contract,” NASA, 26 July 2022. <https://www.nasa.gov/news-release/nasa-prepares-for-space-launch-system-rocket-services-contract/>

Production and Operations Contract” (EPOC), with the intent of having the new company under contract by the end of 2023.¹⁹

However, in October 2023, the Office of Inspector General (OIG) issued a report that the new contract structure was unlikely to reduce the cost as much as NASA predicted, and that the aspirational reduction of 50% was “highly unrealistic.” It noted that the agency’s ability to negotiate lower costs, or to get to a fixed-price contract, would be constrained by the lack of competition for services offered by the system, and by the permission of the contractors to incorporate limited-rights data into both the core stage and the EUS. Beyond that, DST’s ability to achieve economies of scale would be hindered by its inability to compete with the new, low-cost, reusable commercial vehicles reasonably anticipated to come online in the next few years, and the OIG recommended that NASA consider readjusting its lunar plans to account for such systems, beyond the HLS contract.²⁰



... at the beginning of the year 2025, the U.S. is in many ways in a similar situation to that of 2010, with a lunar architecture costing tens of billions of dollars that is unsustainable and unaffordable, and continuing to slip in schedule.



In summary, at the beginning of the year 2025, the U.S. is in many ways in a similar situation to that of 2010, with a lunar architecture costing tens of billions of dollars that is unsustainable and unaffordable, and continuing to slip in schedule. Entrepreneur Dr. Casey Handmer, formerly of NASA’s Jet Propulsion Laboratory, recently called the SLS program a “national disgrace.”²¹ The U.S. has effectively lost another decade and a half in getting humans back to the Moon, now over half a century since the last footsteps on it.

¹⁹ “Exploration Production and Operations Contract (EPOC) Pre-solicitation Synopsis,” NASA, 26 July 2022. <https://sam.gov/opp/8121cbeb1ffc477bb9a342375ab429c7/view>

²⁰ “NASA’s Transition of the Space Launch System to a Commercial Services Contract,” NASA OIG, 12 October 2023. <https://oig.nasa.gov/wp-content/uploads/2023/10/ig-24-001.pdf>

²¹ Casey Handmer, “SLS is still a national disgrace,” Weblog post, Casey Handmer’s Blog, 2 October 2024. <https://caseyhandmer.wordpress.com/2024/10/02/sls-is-still-a-national-disgrace>

PART 2

DESIGN PROBLEMS WITH SLS/ORION

Looking at various aspects of the current Orion/SLS design, it's clear that very little progress is being made in reducing the cost of spaceflight in any significant way by this program over that of the past decades in which the old tech dominated. Moreover, clinging to these legacy systems keeps NASA locked into expensive, wasteful, obsolete designs that the private space industry has long moved past. The following sections examine some of these challenges.

2.1

OBSOLETE ENGINES

NASA's plan to save money also included using engines and other major rocket parts it currently has, rather than paying for new ones, but there are myriad problems with this approach. For example, the launch system consists of a large propellant tank that contains liquid oxygen (LOX) as the oxidizer and liquid hydrogen (LH2) for fuel, of the same diameter as that of the Space Shuttle's external tank, and manufactured in the same facility.²² It initially uses four repurposed Space Shuttle Main Engines (now designated by manufacturer Aerojet-Rocketdyne as RS-25). Because SLS is an expendable rocket, these Space Shuttle era

²² Unlike terrestrial transportation using internal combustion, which uses oxygen from the atmosphere to burn the fuel, rockets must carry their own supply of oxidizer, which can be oxygen itself, or other oxidizers, such as nitrogen tetroxide or nitrous oxide.

engines, which were originally specifically designed for reuse, will be dumped into the ocean on each flight, until the existing supply of legacy engines runs out on the fourth flight (it has only flown once to date), after which new expendable ones have to be manufactured, ironically, at a cost much higher than that of the original reusable ones.



NASA's plan to save money also included using engines and other major rocket parts it currently has, rather than paying for new ones, but there are myriad problems with this approach.



The original Shuttle engines cost about \$40 million each (it's not clear what-year dollars those are). But Aerojet Rocketdyne's new expendable versions cost more. In 2020 a \$1.8 billion contract was issued for 18 engines. That is, about a hundred million each, and each SLS flight requires four of them. To put this in perspective, each engine of the SLS costs more money than a launch of a SpaceX Falcon Heavy, which has been fully operational for years, and has almost as much payload capability as the initial version of SLS, designated Block 1A.²³

Also, like the Shuttle, SLS has two Solid Rocket Boosters (SRBs). However, instead of the four-segment boosters used for the Shuttle, these have five segments, and have no parachute-recovery system, which saves weight and increases payload. Hence, they too are expendable.²⁴ The overall claim in choosing the design has been that, by using proven Shuttle hardware, the new rocket could be developed at a much lower cost than a clean-sheet design. Even assuming this was true, however, there was no mention of how much it would cost to manufacture and operate.

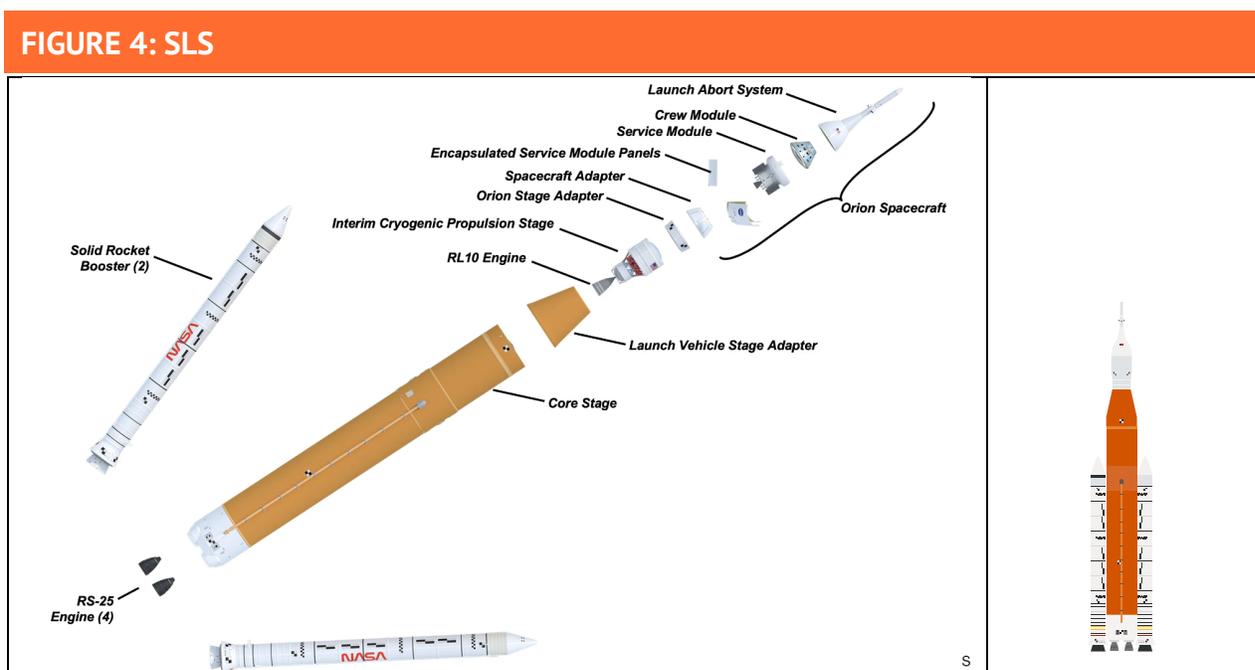
Such large solid boosters, which no other launch system uses, create a very harsh acoustic vibration environment during ascent, which renders the system incapable of delivering payloads that are sensitive to vibration, such as space telescopes or classified national-

²³ Jeff Foust, "Aerojet Rocketdyne defends SLS engine contract costs," *Space News*, 7 May 2020, spacenews.com/aerojet-rocketdyne-defends-sls-engine-contract-costs/

²⁴ Shuttle boosters were recovered and rebuilt, but at the end of the program it was determined that the cost of the recovery fleet exceeded the savings from reusing them, given the low flight rate. SLS flight rate will be much lower.

security payloads.²⁵ Beyond the high marginal cost per flight, the undesirable vibration reduces the number of potential other uses for SLS.

SLS isn't entirely Shuttle-derived. Initially, in a concept called Block 1A, its upper stage is the same upper stage as the United Launch Alliance (ULA) Delta IV, but only for the first three flights. After that, the plan is to upgrade to Block 1B with a new stage called the Exploration Upper Stage (EUS). This stage will increase the payload capability, and will be implemented on the fourth SLS flight. Per congressional direction, the initial SLS payload capability is 70 tons to Low Earth Orbit (LEO), with Block 1B projected to increase to 105 tons with the new EUS. Figure 4 shows the components of the SLS vehicle, which is largely derived from decades-old Space Shuttle hardware, with little new technology.



Source: NASA, www.nasa.gov/wp-content/uploads/2023/03/sls-4704-sls-rev-32-publicrelease-dac3-16-9-111623-r6.jpg

2.2

LESS-EFFECTIVE PROPELLANT SELECTION

Due to the requirement that SLS be based on Shuttle technology, another design flaw carried over from the Shuttle is the choice of propellants: liquid hydrogen fuel and liquid

²⁵ Shuttle astronauts invariably noted that the ride on ascent got much smoother after SRB separation, when the only propulsion was the much-smoother liquid-fueled SSMEs.

oxygen as the oxidizer.²⁶ Liquid hydrogen offers the highest specific impulse of conventional chemical rocket fuels, which makes it more efficient in terms of propellant usage, but at a cost. It is a very low-density fuel, requiring a large propellant tank to contain a given mass of it. This adds weight to the dry mass of the vehicle, and drag in the atmosphere, with a corresponding performance reduction in terms of payload. Beyond that, while hydrogen's fuel efficiency is high at higher velocities and in vacuum, it's not well suited for the initial liftoff and ascent in the atmosphere. For this reason, few launch systems have used it in a sea-level stage (only Shuttle, SLS, and the now-retired Delta IV).

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Due to the requirement that SLS be based on Shuttle technology, another design flaw carried over from the Shuttle is the choice of propellants: liquid hydrogen fuel and liquid oxygen as the oxidizer.

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2.3

EXPENDED COMPONENTS

Another problem with the contract is the mandated use of expended components.²⁷ Though it was largely derived from the partially reusable Space Shuttle (in which boosters were recovered and the orbiter landed intact), the propellant tank was expended. The Space Shuttle main engines that had been designed for reuse and in fact had been reflown many times, instead end up in the Atlantic, along with the SLS first stage when it is expended. The solid boosters, which had been recovered from the ocean and rebuilt in the Shuttle program, are expended as well.

2.4

PROBLEMS WITH ORION

As with Apollo, the Orion capsule needs a service module to provide power, propulsion, and life support. An exploded view of Orion with its service module and launch abort system is depicted in Figure 5.

²⁶ “NASA’s Space Launch System Reference Guide,” National Aeronautics and Space Administration, nasa.gov, 2025. <https://www.nasa.gov/wp-content/uploads/2022/03/sls-reference-guide-2022-v2-508-0.pdf> (9 May 2025).

²⁷ Ibid.

FIGURE 5: ORION MODEL: A SCALED-UP VERSION OF THE CREW MODULE FROM APOLLO



Source: NASA, <https://www.nasa.gov/wp-content/uploads/2023/02/microsoftteams-image-17-1-1.jpg>

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This escape tower adds mass (and cost) to the system, reducing the amount of useful payload. It also introduces new hazards.
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The Orion capsule is a scaled-up version of the venerable Apollo capsule of the 1960s. While Apollo carried a crew of three, Orion carries a crew of four. As in Apollo, Orion has a solid-motor “tractor” launch-escape system on top to rapidly pull the capsule away from

the launch vehicle with a solid-rocket motor in the event of a problem during ascent.²⁸ It is jettisoned after the rocket reaches a safe altitude, after which it is no longer necessary. This escape tower adds mass (and cost) to the system, reducing the amount of useful payload. It also introduces new hazards. For example, if it fails to jettison after an otherwise nominal launch, it would prevent the parachutes from deploying during descent, resulting in loss of the crew.²⁹

In late October 2024, almost two years after the flight, NASA revealed that it had determined the root cause of the unexpected char loss of Orion's ablative shield, but still provided no details, saying that it was going to continue testing through November.³⁰ Finally, in early December, the agency announced that the cause was gas trapped under the ablator that resulted in pressure build up as it was heated during entry, causing pieces of the shield to be blown off. In fact, it wasn't a failure that had been unpredicted (which may have been a key reason for the delay and reluctance to reveal it), but the agency had done nothing to mitigate the risk. Moreover, despite this, NASA announced a decision to fly it without modification for the next mission, Artemis II, instead alleviating the problem by flying a less-stressful thermal trajectory on re-entry. The modification would await Artemis III. This announcement was presumably to minimize further schedule slippage, and it was decried by many, including safety experts and former astronauts, and many considered it something that NASA would never have allowed a contractor to do (citing as an example their refusal to allow Boeing to return astronauts on its flawed Starliner flight to the International Space Station).³¹ It's worth noting that, with regard to safety, NASA does not plan to do an uncrewed test flight of the EUS; it will fly crew on the very first flight of Block 1B with its new EUS upper stage.

²⁸ The SpaceX Dragon capsule uses a more efficient liquid-propellant "pusher" system for abort, with engines that fire behind it, and has other potential uses on a nominal flight.

²⁹ "NASA's Management of Space Launch System Block 1B Development," NASA Office of Inspector General, 8 August 2024. <https://oig.nasa.gov/wp-content/uploads/2024/08/ig-24-015.pdf>

³⁰ Jeff Foust, "NASA finds, but does not disclose, root cause of Orion heat shield erosion," *Space News*, 29 October 2024. <https://spacenews.com/nasa-finds-but-does-not-disclose-root-cause-of-orion-heat-shield-erosion/>

³¹ Berger, Eric "After critics decry Orion heat shield decision, NASA reviewer says agency is correct," *Ars Technica*, 6 December 2024. <https://arstechnica.com/space/2024/12/former-flight-director-who-reviewed-orion-heat-shield-data-says-there-was-no-dissent/>,



NASA does not plan to do an uncrewed test flight of the EUS; it will fly crew on the very first flight of Block 1B with its new EUS upper stage.



Re-entry into the Earth's atmosphere requires a robust heat shield to protect the capsule from the high temperatures encountered during the compression heating of the atmosphere as the capsule decelerates. The Shuttle used silica tiles, which turned out to be a large maintenance problem. Orion uses Avcoat, a composite of silica fibers in a matrix of phenolic resin. It was used in the Apollo capsule and some early Shuttle flights. It is an ablative shield, which means that one of the ways it keeps temperature down is to burn away material as it heats, which carries the heat away with it. As such, the Orion capsule is not fully reusable in that it requires significant maintenance between flights to refurbish it.

NASA understands the economic and technological value of moving to reusable systems, since it has been using them to transport people and goods to the ISS. But using the old rockets it has first keeps in place the legacy system that makes space-flight expensive and infrequent, leading NASA to make each flight fulfill all goals, which increases the complexity of the mission, which causes delays and increases expense.

2.5

THE SINGLE-LAUNCH RELIABILITY MYTH

The SLS flight rate is very low (initially only once per two years, and it has already been more than two years since the first SLS flight in November 2022), with little ability to ramp up much past once or twice per year.³²

While it's not the only argument SLS proponents use to defend the program, they have historically partially justified the system by making the following argument:

The greater the number of flights a mission requires, the lower the probability of successfully delivering all the elements needed for it, because it is a multiplication of the individual probabilities of success of each rocket flight. As an example, former NASA Administrator Mike Griffin and SLS proponent put together a table describing this

³² Ibid.

mathematically as a function of reliability (e.g., 20 flights of a 98% reliable launcher would have a probability of success of ~67%).³³

Moreover, because of NASA's superior experience and processes developed over decades, and its wise use of proven flight hardware such as engines and solid rocket motors, and its upper stage, SLS will probably have greater than 98% reliability, compared to commercial rockets.³⁴ SpaceX blew one up in summer 2015, so their demonstrated reliability is only 24/25, as of June 2016, (or 96%). Thus, a mission that required 30 successful Falcon flights would only have 0.96 to the 30th P_m, or about 30%, a less than a one-in-three chance.³⁵

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There are two major problems with this argument:

First, launching everything on a single vehicle is putting all your eggs in one basket. The probability of mission loss has a floor based on the reliability of the launch system. NASA used this method in Apollo because it had no choice, given its limited experience at the time in rendezvous, docking/mating, and propellant transfer. The space industry has no such limitations today, with extensive experience with assembling and providing logistics for the ISS for over a quarter of a century. Just as early airplane flights were once fraught with peril and had low reliability, so did early voyages to space. But nowadays, given our vast experience with airplane flights and the millions of flights that have occurred, flying is now the safest means of transport. This is the sort of experience trajectory that space flight has achieved, yet NASA continues to approach flights as pioneering missions from the early years.

³³ Alex Longo, “Starship Faces Performance Shortfall for Lunar Missions,” *America Space*, Apr 20 2024, <https://www.americaspace.com/2024/04/20/starship-faces-performance-shortfall-for-lunar-missions/>

³⁴ G. R. Cates, C. Stromgren, W. M. Cirillo, and K. E. Goodliff, “Launch and Assembly Reliability Analysis for Mars Human Space Exploration Missions,” NASA Technical Reports Server (NTRS), 2020.

³⁵ Note that this argument is much more difficult to make in 2025, when Falcon 9 now has at least 500 successful flights, with only two failures, or a reliability greater than 99%.

Second, minimizing launches for lunar missions also minimizes launch cadence, which actually reduces launch reliability. Reducing launches changes the learning curve over time, and the launch crew has less proficiency with less-frequent flights. Back in 2013, planetary scientist and retired NASA Advisory Council member Steve Squyres expressed similar concerns:

“I’m deeply worried,” he told [Congresswoman] Edwards, because no other human spaceflight system has had such a low anticipated launch rate. The first SLS launch is expected in 2017, the second in 2021, and then once every two years thereafter. SLS and the Orion spacecraft need to be adequately funded “to be proven out on a pace that really supports ... a safe pathway” to cis-lunar space,” Squyres insisted.³⁶

Conversely, multiple flights have the opposite effect, increasing reliability by creating a high launch tempo, with associated experience. For example, while SpaceX’s Falcon has had a few launch failures initially, it has also flown hundreds of flights over the past few years with no launch failures.³⁷ Failure of any single launch does not result in overall mission failure, unless there is a unique mission-critical payload on that flight (as opposed to, say, propellant), because it just means sending up another element. If NASA is sending up unique payloads without which it cannot do the mission, NASA is doing it wrong.

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When a single launch is the whole mission, a launch failure is a catastrophic mission failure. Creating a transportation system overcomes that approach.

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Multiple launches make a system instead of pioneer exploration, which the U.S. space program is long past. When a single launch is the whole mission, a launch failure is a catastrophic mission failure. Creating a transportation system overcomes that approach. Testing multiple flights is the difference between covered wagons on dirt trails and modern

³⁶ Marcia Smith, “Little love for asteroid retrieval mission; Squyres deeply worried about SLS launch rate,” SpacePolicyOnline, 23 May 2013 <https://spacepolicyonline.com/news/little-love-for-asteroid-retrieval-mission-squyres-deeply-worried-about-sls-launch-rate/>

³⁷ This information was determined by dividing the number of launches by the number of flights. It uses data from 2015 to 2025.

vehicles on super-highways. There will be crashes in either case, but a higher frequency of flights means more missions are accomplished—and more efficiently. Whatever payload is lost on one flight (e.g., propellant) can be delivered on the next one, because high flight frequency means no flight would have to carry an irreplaceable mission element. Let's consider a truck analogy. Suppose we build a house in a factory, ready to live in, and then deliver it to its final destination on a giant truck. It's a very expensive payload, because of all the value added in the factory where it was built. The success of getting the house to the residential lot is totally dependent on the truck not crashing somewhere along the way. But trucks do crash occasionally, making this a gamble. And if it happens, a hundred-thousand-dollar (or more) house is lost.

That's why we build houses on site from much smaller, less-expensive parts, and we add value by assembling them there. That way, a lost shipment is not that big of a deal, and can be overcome by sending out another load of cheap concrete, plywood, studs, or drywall. This is the way we do things on Earth. There is nothing magical about space that means we should do it any differently there, at this evolved stage of our experience.

In other words, by planning for contingency flights, one can arbitrarily increase the probability of mission success, as long as there is no irreplaceable payload. But more importantly, reducing number of flights to reduce risk, as SLS proponents recommend, reduces vehicle reliability by reducing flight rate.

It's important to distinguish terms. As David Chevront, an engineer at Johnson Space Center at the time, but now retired, pointed out in 2015:

Although the curves follow a similar shape, demonstrated reliability is fundamentally different from reliability growth. While reliability growth involves correction of problems discovered from flight experience, demonstrated reliability is concerned strictly with increasing the number of trials to increase the level of certainty of the actual reliability of an unchanging design. High demonstrated reliability is often required for unique or exceptionally high value payloads. In such instances, launch on vehicles having the highest demonstrated reliability but significantly higher cost may be justified as a degree of "insurance" against loss. One risk strategy is to launch high value payloads on well-proven LV's until high reliability is demonstrated to reach similar confidence for new, lower-cost options.³⁸

³⁸ Charles Miller and Alan Wilhite, "Economic Assessment and Systems Analysis of an Evolvable Lunar Architecture that Leverages Commercial Space Capabilities and Public-Private-Partnerships," NextGen Space LLC (funded by NASA grant), 53-54.

As Chevront notes, the general philosophy should be to allocate different types of payloads to different types of launch systems, depending on the value of the payload and the system reliability. For instance, cheap bulk cargo, like propellant, water or other consumables should travel up on cheap launchers, even if they're not reliable, because there is little of value at risk.

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... the general philosophy should be to allocate different types of payloads to different types of launch systems, depending on the value of the payload and the system reliability.

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In fact, this is an excellent kind of payload for new, untested rockets, as a way to wring the bugs out of them. It's also a good way to incorporate international cooperation, by allowing other countries to deliver propellant as a contribution to a mission. High-value payloads, such as costly hardware, or humans, should travel on proven launchers.³⁹

Americans have landed on the Moon and are past the pioneering stage. Keeping legacy systems in place ensures that space-flights will remain bespoke, and therefore difficult, and therefore expensive, and therefore infrequent, making the per-unit cost of each launch exorbitant. It will take a change of paradigm to break out of this cycle.

Now is the time to move on, creating a transportation system that uses our highest capabilities, which are to be found in the achievements of private space companies. Concerning the SLS specifically, NASA has already implicitly admitted that the ostensible purpose of the SLS—to allow a lunar mission in a single launch as with Apollo—is already gone because the SLS needs the Gateway as an intermediary point, and it cannot carry a lander on the same flight as the capsule. Any return to the Moon will require multiple launches, and once that is accepted, there are a number of different ways to get the Americans back to the Moon.

³⁹ Rand Simberg, “Ending Apolloism, Removing the Mental Roadblocks that Continue to Confine Us to Low Earth Orbit,” *Trans terrestrial Musings*, 30 June 2016, 34-37.

PART 3

CONTRACTING WITH COMMERCIAL SPACE TRANSPORT

In contrast to NASA's current approach, private space companies have developed newer, leaner, reusable systems. Just as transoceanic shipping and airline travel evolved from each trip being uniquely designed pioneering journeys into the unknown to being an efficient, lower-cost, and frequent form of transportation, so spaceflight should follow this natural evolution.

NASA recognizes this evolution, having contracted with private space companies for many auxiliary aspects of spaceflight, but has resisted the transformative change that would allow the United States to assume global leadership. By helping enable a transportation system utilized by NASA but using entirely private space technology, NASA would take advantage of market-driven efficiencies and technological advancements that currently exist, which would dramatically reduce costs and allow the U.S. the frequency of access required to further scientific, economic, and transportation goals. The following sections examine how a move to NASA contracting space flight with commercial space technology will not only solve the Orion/SLS problems, but will allow the United States to leap forward in identifying and harnessing space resources and furthering scientific discovery.

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In contrast to NASA’s current approach, private space companies have developed newer, leaner, reusable systems.

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3.1

REDUCED COSTS

For the delivery of passengers and payload to space, we have the SpaceX Falcon family, both Falcon 9 and Falcon Heavy, which use LOX/kerosene for both boosters and upper stage. These are extremely reliable rockets, with hundreds of consecutive successful flights from the Falcon 9, and zero failures of the Falcon Heavy. For those who argue that other launchers are not yet “human rated,” it can deliver crew to orbit with the Crew Dragon without having to use the others.⁴⁰

Now also available is the United Launch Alliance’s (ULA) new Vulcan rocket, which replaces the Atlas V. It has a LOX/methane first stage, and a LOX/hydrogen Centaur upper stage. Its LEO payload is 27 metric tons (MT), and it can use 12 MT for trans-Lunar injection (TLI).

Blue Origin recently debuted its New Glenn rocket with a successful launch, though the landing attempt of the booster failed.⁴¹ Like Vulcan, it has a LOX/methane first stage (using the same engines, which are in fact produced by Blue Origin) and a LOX/hydrogen upper stage. It can deliver 45 MT to low Earth orbit (LEO), and seven to TLI. The launch systems and their key characteristics are summarized in Table 2. These are the most likely candidates, but it’s possible that other companies, such as Rocketlab, Stoke Space, Firefly, Relativity, and others, could compete for Artemis missions as well.

Table 2 shows the abundance of qualified commercial launch providers for return to the Moon.

⁴⁰ The author has argued in his book *Safe Is Not An Option* that the concept of human rating is an archaic relic of the 1960s, and the supposed lack of it should not be used as an excuse to delay doing crewed spaceflight or to stifle competition.

⁴¹ It would have been surprising if the landing had worked on the very first attempt, and in any event, landing boosters are not necessary to get people and hardware to the Moon.

All the payload numbers are for orbits due east from Cape Canaveral, to 28.5 degrees inclination, which is a reasonable orbit for staging missions to the Moon (it's what the Apollo missions used). They cost on the order of \$100M per flight (what SLS alone spends in less than a month), and just a little over half that for the Falcon 9. Forty reusable Falcon Heavy launches could deliver the equivalent payload of 17 SLS launches for about the cost of a single SLS flight.⁴²

TABLE 2: QUALIFIED COMMERCIAL LAUNCH PROVIDERS

VEHICLE	Falcon 9	Falcon Heavy	Starship/ Superheavy	New Glenn	Vulcan
Provider	SpaceX	SpaceX	SpaceX	Blue Origin	United Launch Alliance
Price (\$ millions)	~60	~100	50 ⁴³	68-110	? ⁴⁴
Reusable	Partially	Partially	Fully	Partially ⁴⁵	None
Payload To LEO (MT)	23	64	>100 (TBD)	45	27 ⁴⁶
Flight history	Several hundred	11 (no failures)	Still in flight test	One successful flight (booster landing failure)	One successful flight (solid booster anomaly), but many national security payloads booked
Propellant	LOX/ kerosene	LOX/ kerosene	LOX/ methane	LOX/methane, LOX/hydrogen (upper stage)	LOX/methane, LOX/hydrogen (upper stage)

Source: "Falcon 9," SpaceX <https://www.spacex.com/vehicles/falcon/9/>, "Falcon Heavy," Space X, <https://www.spacex.com/vehicles/falcon/heavy>, "Starship," SpaceX, <https://www.spacex.com/vehicles/starship> New Glenn, <https://www.blueorigin.com/new-glenn> "Vulcan," United Launch Alliance, <https://www.ulalaunch.com/rockets/vulcan-centaur>

Figure 6 shows the cost differential between SLS and Falcon Heavy is staggering, and would be even greater for Starship.

⁴² This is based on the \$4.1 billion estimate for an SLS flight, and about \$100 million per Falcon Heavy flight (SpaceX's current price), and a payload of 70 tons for SLS and 57 tons for Falcon Heavy.

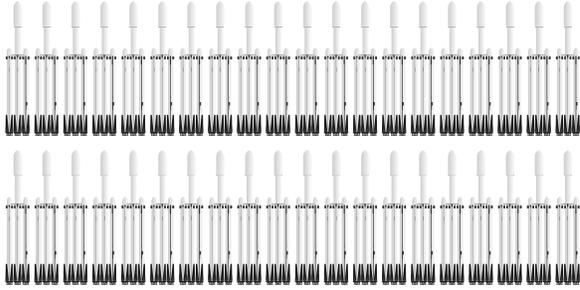
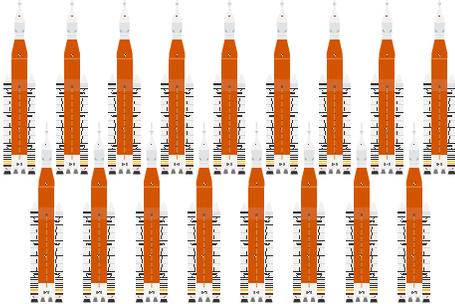
⁴³ SpaceX has not announced a price for a launch, but based on the fact that the company wants to replace the Falcon family with it as soon as possible, it will presumably be less than the price for that vehicle, and can be if it meets its full reusability goals.

⁴⁴ Only known to its government customer, but the company has stated that it expects launch prices to be affordable for commercial customers.

⁴⁵ The booster is planned to be recovered, despite the failure to do so on the first flight. The company has plans for a reusable upper stage, called "Jarvis," but it's unclear when it will be available.

⁴⁶ Can be greater, depending on how many solid boosters are used.

FIGURE 6: FALCON HEAVY VS SLS BLOCK 1A: FLIGHT COST COMPARISON TO DELIVER EQUIVALENT PAYLOAD

40 Falcon Heavys	17 SLS Block 1As
	
Payload: ~1,200 Metric tons	Payload: ~1,200 Metric tons
Cost: ~\$4 Billion	Cost: ~\$68 Billion

And of course, that doesn't take into account SpaceX's Starship, which will almost certainly be capable of delivering more payload than SLS can within a year or so, after resolving the problems that caused the latest three flights to fail (which was a new version, with new propulsion plumbing and was likely due to resonance problems that will be sorted out). It will not only be able to launch heavy payloads (two to three times that of SLS), but with its nine-meter fairing diameter, very large ones. Given that it's fully reusable, and that SpaceX wants it to replace the Falcon family as soon as possible, its flights will likely be priced at less than Falcon 9, or less than \$60M. If it were priced higher, it wouldn't obsolesce the Falcon family, which is one of the program's goals.



Ending the SLS program as soon as possible will free up over \$2 billion per year from SLS itself, ~\$250 million from ending work on ML-2,⁴⁷ and ~\$600 million per year from the EUS, for a total savings of ~\$3 billion per year.



⁴⁷ Dirk Knop, "Artemis: Cost explosion for mobile launcher Mobile Launcher 2," *Heise Online*, 2 September. 2024. <https://www.heise.de/en/news/Artemis-Cost-explosion-for-mobile-launcher-Mobile-Launcher-2-9854393.html>

Ending the SLS program as soon as possible will free up over \$2 billion per year from SLS itself, ~\$250 million from ending work on ML-2,⁴⁸ and ~\$600 million per year from the EUS, for a total savings of ~\$3 billion per year.⁴⁹ If the SLS isn't canceled immediately, but only flown for the next two planned flights, the U.S. could still save the ~\$850 million per year by canceling ML-2 and EUS, which would only be needed for the fourth flight. Canceling Orion would perhaps provide an additional \$1.4 billion per year. Ending Gateway would increase the savings by perhaps another \$1 billion per year, but there would be international political ramifications to this, which is a multi-national program, like ISS. It could perhaps be a useful facility if put in a more useful location, such as the Earth-Moon Lagrange point EML-1, between the Earth and the Moon. Finally, ending SLS will free up another pad at Kennedy Space Center for a second Starship launch tower, potentially accelerating that program, or for use by some other launch provider.⁵⁰

In summary, there is a plethora of launcher, in-space transportation, and landing vehicle possibilities to provide a number of mission concepts to get Americans back to the Moon quickly and relatively affordably, compared to the current Artemis mission CONOPS. Teams of aerospace engineers should do the trade studies to determine which is the best, and soon.

3.2

MODERN LAUNCH TECHNOLOGY

SLS, like the legislation that created it, prescribes maintaining the workforce of the established legacy system, locking in old and obsolete technologies. Private companies, on the other hand, design launch systems that have to satisfy the launch market, and in the case of at least two of them (SpaceX and Blue Origin) exist to minimize the cost of getting to orbit in furtherance of their own corporate goals. They do this by utilizing the most effective current launch technologies, such as reusability, modern engines, and more-effective propellant combinations, knowing that if they do anything less they will both lose to the competition and not achieve those corporate goals. While United Launch Alliance does use solid rocket motors for its Vulcan booster, they are not the large ones that cause

⁴⁸ Dirk Knop, "Artemis: Cost explosion for mobile launcher Mobile Launcher 2," *Heise Online*, 2 September 2024. <https://www.heise.de/en/news/Artemis-Cost-explosion-for-mobile-launcher-Mobile-Launcher-2-9854393.html>

⁴⁹ The savings will probably be somewhat less, due to contract-termination costs.

⁵⁰ Richard Tribou, "New or Retooled Cape Canaveral Launch Pads Considered for SpaceX Starship," *The Orlando Sentinel*, 19 Feb. 2024. https://phys.org/news/2024-02-retooled-cape-canaveral-pads-spacex.html#google_vignette (9 May 2025).

the brutal vibrations of the SRBs, which SLS uses because part of its raison d'être is to utilize Shuttle components. For all players, workforce is a cost, not a feature, and they attempt to minimize it for maximum productivity rather than, as is the case with the government program, maximizing jobs in favored zip codes. Simply put, the incentives driving the designs of the private sector vehicles are dramatically different from those of government programs, resulting in high cost and low performance for the latter and increasingly low costs and improved performance from the former, due to increasing market competition.



Simply put, the incentives driving the designs of the private sector vehicles are dramatically different from those of government programs, resulting in high cost and low performance for the latter and increasingly low costs and improved performance from the former, due to increasing market competition.



3.3

REDUCED DELAYS

Relying on and encouraging competition among private space companies should keep costs lean, keep technology cutting edge, and gain efficiencies that are likely to reduce delays. Such advances, as private space companies have already demonstrated over the years, would make spaceflight a routine form of transportation, reducing delays considerably. Regarding delays over which the space program has no control, such as international efforts, as discussed previously, moving to a space transportation system marked by frequent launches, and using those launches to deliver less-essential materials to space allows for international cooperation in areas that don't affect, and therefore won't delay, the overall mission.

Not only does delay cost time and money, it diminishes our potential to harness space resources that now exist. Unquestionably, the vast percentage of potential resources in the solar system do not reside on Earth. In terms of energy, the greatest source is the natural fusion reactor of the sun itself, of which only a minuscule percentage is captured by Earth. A great deal more can be harvested in space. In terms of materials, the asteroids contain

unfathomable amounts of precious metals and rare earths, worth quadrillions on this planet at current prices (though of course if they were imported, those prices would plunge). Doing so could usher in an era of unimaginable abundance for everyone on, and ultimately off, the planet. But increasingly, other countries have their own designs on space, especially China. Delay will cost the U.S. opportunities.

3.4

THE COMPETITION FROM CHINA

China is showing how seriously it takes space exploration. Instead of copying NASA (as the Soviet Union did in the 1980s with its failed Buran knock off of the Space Shuttle), it is copying SpaceX and other innovative American companies. If the U.S. is to remain preeminent in space development, we have to become equally serious, in both our technical approach and our willingness to accept risk.

We know that there is water ice on the Moon, and perhaps other volatiles such as carbon, not just in the permanently dark craters of the poles, but perhaps in other locations as well. Water is essential not just for life, but it also can be cracked into its constituent hydrogen and oxygen to make high-performance rocket propellant, and the oxygen itself is needed for human habitats. The silicates of the regolith contain not just more oxygen, but elements such as aluminum, silicon, and titanium, among others, that can be used to construct structures, both on and off the Moon, and electronics. The far side of the Moon, which to date only the Chinese have visited, would be an ideal location for a radio telescope, which could be very large due to the low lunar gravity.

China has been actively pursuing lunar exploration through its Chinese Lunar Exploration Program (CLEP), also known as the Chang'e Project.⁵¹ This program includes a series of missions aimed at orbiting, landing, and returning samples from the Moon. The Chang'e 6 mission was designed to collect samples from the far side of the Moon, an area previously unexplored for sample return, marking a significant scientific achievement. The mission successfully returned to Earth with lunar samples from the Apollo Basin within the South Pole (Aitken Basin) in June 2024. Additionally, forthcoming missions like Chang'e 7 (planned for 2026) and Chang'e 8 (planned for 2028) will explore the lunar south pole for

⁵¹ Blaine Curcio, "China Lays Out Plan to Accelerate Lunar Ambitions," SpaceRef.com, *SpaceRef*, 28 July 2023. China has been actively pursuing lunar exploration through its Chinese Lunar Exploration Program (CLEP), also known as the Chang'e Project. (9 May 2025).

resources, including potential water ice, and demonstrate in-situ resource utilization technologies like 3D printing with lunar regolith.⁵²

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This initiative is part of China’s broader ambition to not only reach the Moon but to establish a human presence there, echoing the historical significance of the U.S. Apollo missions but with modern technological advancements and goals.

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China has announced plans for human lunar landings by 2030, with the spacecraft named Mengzhou (Dream Vessel) and the lunar lander named Lanyue (Embracing the Moon).⁵³ This initiative is part of China’s broader ambition to not only reach the Moon but to establish a human presence there, echoing the historical significance of the U.S. Apollo missions but with modern technological advancements and goals. However, the Lanyue uses a “crasher” stage that is sacrificed in order to allow enough propellant for the ascent portion to take off again. This indicates that they are in a hurry, and less concerned with reusability/sustainability for their lunar activities right now. This should provide impetus for us to get Americans back there as soon as possible, and we should be willing to accept the same risk levels for crew safety as we did in Apollo, for the same reasons.

Beyond the initial landings, China plans to establish an international lunar research station at the Moon’s south pole by 2040, with a program it calls the International Lunar Research Station (ILRS).⁵⁴ Only a few countries have joined this initiative to date, but one of them is Russia. This reflects China’s strategy to expand its influence in space through collaborative efforts, potentially competing with or (more hopefully) complementing projects like the

⁵² Andrew Jones, “China’s Chang’e-6 probe arrives at spaceport for first-ever lunar far side sample mission,” *Space News*, 10 January 2024, <https://spacenews.com/chinas-change-6-probe-arrives-at-spaceport-for-first-ever-lunar-far-side-sample-mission/> (7 May 2025).

⁵³ “China Names its Capsule and Lander for its Upcoming Human Lander Missions,” *phys.org*, 27 Feb 2024. https://phys.org/news/2024-02-china-capsule-lander-upcoming-human.html#google_vignette (9 May 2025).

⁵⁴ Andrew Jones, “China invites bids for lunar satellite to support crewed Moon landing missions,” *Space News*, 14 February 2025. www.spacenews.com/china-invites-bids-for-lunar-satellite-to-support-crewed-moon-landing-missions/

Artemis program. On February 14th of this year, China invited bids on a remote-sensing satellite in lunar orbit to support its crewed landing plans and welcomed commercial Chinese entities in the process, though no non-Chinese firms were invited, despite the supposed multi-national nature of ILRS, which China is leading.⁵⁵



Congress expects NASA to be doing its utmost to keep up with Chinese advances in space. This will require NASA and the U.S. space program to leap forward, not remain where it is.



Congress expects NASA to be doing its utmost to keep up with Chinese advances in space. This will require NASA and the U.S. space program to leap forward, not remain where it is. It's important to determine what the requirements of that new architecture should be.

3.5

GUIDANCE FOR NEW ARCHITECTURE

3.5.1 WHAT WE DON'T NEED

If we are to get Americans back to the Moon as quickly as possible, we must understand that there is no requirement to use SLS (or indeed any launch system of its payload class) to do so. That this has been a requirement for the decade and a half since SLS's existence was invoked in federal law is the primary thing holding back progress, because it diverted resources from hardware actually needed to get back to the Moon. In the name of efficiency and effectiveness, and given the advanced technological achievements of private space companies, there's no reason for NASA to be in the launch business at all.

The focus, for both the taxpayer and NASA, must be on achieving the goal as soon as possible, as cost-efficiently as possible. If jobs are created or preserved as a result of the chosen architecture, that should be considered a bonus, but not a mission goal.

⁵⁵ Ibid.

Also, if we want to achieve our goals in space in a timely manner, we cannot insist on absolute safety. There is no such thing as a safe mission to other celestial bodies, and there never will be, because there is no such thing as safe travel anywhere, even on a trip to the grocery store. Every action we take, every decision we make, carries risk. In Apollo, the astronauts knew there was a chance not only that the mission wouldn't succeed, but also that they might not make it back alive. While the actions of both crew and Mission Control were admirable, we were very lucky that we didn't lose the crew in Apollo 13. If the LOX tank had exploded on the way back instead of on the way out, with no lunar module as backup for power and life support, they would surely have suffered a miserable death.



...if we want to achieve our goals in space in a timely manner, we cannot insist on absolute safety.



So the question is: What level of risk are we, as a nation, willing to accept? What is it worth? There is no question that we have no shortage of Americans willing to accept risk on our behalf, because they do it every day in the military. Is 50% chance of loss of crew acceptable? Is 10%? Is one? There is no way to get to zero, so risk has to be balanced against success. The more accepting of risk we are, the sooner it will happen. It is important to establish some acceptable risk level for lunar missions, politically, so that mission designers know the limits.

If Congress' goal is to establish a permanent presence on the Moon before China does, Congress should consider what may seem to be a radical proposal: getting people to the Moon is not that difficult. What was hard, in the 1960s, was (in JFK's words) "returning him safely to Earth." The space community has been saying for decades, when discussing the U.S.' return to the Moon, that it should be "this time to stay." If we are willing to accept the risk, the easiest, fastest, least-costly option would be first to land a base with needed equipment and supplies and ensure that it is functional, then send the first crew. That crew can be resupplied in the same manner as the base was established. In parallel with their initial research and exploration, we would develop the means to bring them back, but it would certainly allow us to get there first (unless, of course, the less risk-averse Chinese decide to do that before us).

So having established what are not requirements (SLS, prescribed contractors and workforces, 100% safety), what are the requirements?

3.5.2 IMMEDIATE REQUIREMENTS

In Apollo, the mantra was “waste anything but time.” So the amount of money that Congress is currently spending on Artemis is not the biggest problem. The biggest problem is that, even with that ridiculous expenditure, NASA’s legacy approach brings unacceptable delay. The space program needs to find an alternative mission architecture at which to redirect those resources that will actually do the job.

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... the elements of the architecture should be, to the degree possible, “off the shelf.”

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The next requirement is that the elements of the architecture should be, to the degree possible, “off the shelf.” With the possible exception of the lander, all of the transportation elements should be available either currently or, at most, within a year or two (though some modifications may be required). If someone can come up with a quick-and-dirty lander that will be better than the currently planned HLS Starship in terms of making the rest of the job easier, that should be considered. Such a lander might simply take a page from Apollo, and have separate descent and ascent stages. While it wouldn’t be acceptable for later sustainable lunar operations, for the initial flights, the descent stage might be simply a “crasher” stage (like the “sky crane” concept that landed the Perseverance rover on Mars) to save mass and money, since in this case it can be single use.⁵⁶ While reuse of all mission elements is desirable if possible, it cannot be required, at least not for the lander, if it is to meet the immediate schedule. The mission concept of operations (CONOPS) should in fact be much like Apollo, except that, given the decades of advances and experience in orbital rendezvous, docking, and assembly since then, it can be performed with multiple launches.

⁵⁶ Gabrielle Fonrouge, “NASA releases video of ‘seven minutes of terror’ Mars landing,” *New York Post*, <https://nypost.com/2021/02/22/nasa-releases-seven-minutes-of-terror-mars-landing/>

Finally, it should be all-American, meaning that the mission should be national rather than international. Attempting to do it with international partners will cause delays with negotiations, increase programmatic complexity, and risk additional failure in communication and program management, making it very unlikely to meet the goal. Note, though, that this does not in any way mean abandoning the Artemis Accords themselves; those policies will be key to the less-immediate architectures that will later provide sustainability and permanent lunar bases, and they are important for establishing consensus and customary international law to establish the ability to utilize lunar resources. The only exception to this requirement might be Orion's planned European service module, if it is actually judged in the needed trade studies to be of sufficient value to the project.

3.5.3 NEAR-TERM REQUIREMENTS

Beyond the initial forays to reestablish our basic capability to get humans back to the Moon, the space program needs to develop infrastructure that is sustainable—that is, affordable to use on an ongoing basis—by both government and commercial customers.⁵⁷

It should also be scalable, so that if demand for its use increases, it can rapidly increase supply as well, while reducing costs. This in turn implies low marginal costs.

The key to both affordability and scalability is high activity rates with low marginal costs. The marginal cost of an item is the cost of the next one, given that it is already in production. It doesn't include fixed costs like rent or overhead. It can be computed as: $\text{Cost}(n+1) - \text{Cost}(n)$ where Cost is a function of "n" and "n" is the number of items produced. In the case of expendable rockets, it is the cost of producing the rocket, including propellant, and of the staff needed to launch that specific flight, but doesn't include things like fixed costs of facilities or overhead. Because we throw the rocket away each time, traditionally the marginal cost of launch has been very high, which is why we haven't done that much of it, compared to other modes of transportation in which the vehicle is not disposed of after each use.

⁵⁷ Julia Seibert, "Space Insider," spaceinsider.tech, *Space Insider*, 31 July 2024. <https://spaceinsider.tech/2024/07/31/ula-vs-spacex/> (9 May 2025).



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Reusability and refueling change the game. For a fully reusable rocket, or in-space stage, the marginal cost is the cost of the propellant. As an example, the price of a United Launch Alliance Atlas V ranged from about \$100 million–\$150 million, depending on how many (expendable) solid boosters it needed. For a fully reusable SpaceX Starship, the marginal cost is basically the cost of propellant, or just a few million dollars for the LOX and liquid methane. This is revolutionary, in that traditionally, at the low flight rates of rockets that were thrown away, the cost of the propellant was in the noise of the total launch cost. For example, fuel costs can be as much as 40% of the cost of an airliner flight, so airlines are willing to make investments in aircraft modifications, such as winglets or even new aircraft, if they promise significant fuel savings.⁵⁸ Launch providers have never cared about propellant costs because they are such a small fraction of the total. But once reusable rockets are flying at high rates, which is affordable because the rockets aren't being thrown away on each flight, they will actually start to care what the propellant costs, which will mean that the problem of high launch costs will finally be addressed.

So to have affordability and scalability, in both launch and in-space transportation, including lunar transportation, the space program needs fully reusable transportation systems with ubiquitous propellant depots. In other words, space transportation has to become like ground transportation, and companies like SpaceX are leading the way.

⁵⁸ "How Much Does it Cost to Fuel a Commercial Airliner," [simpleflying.com](https://simpleflying.com/commercial-airliner-fuel-cost/), *Simple Flying*, 9 Dec. 2023.

PART 4

ALTERNATIVE ARCHITECTURES VIA A MOVE TO PRIVATE COMPANIES

4.1

INTRODUCTION

For now, tabling the intermediate sustainable cislunar transportation infrastructure and its reusability/refuelability requirements discussed previously, this brief's focus is on the more urgent task of laying out scenarios for the quickest sustained access back to the Moon without SLS. Removing SLS also removes the need for the EUS, the MLPs, and perhaps even Gateway, though the latter could be of potential value in a more useful orbit that would be allowed by ending SLS. This would free up billions in funding to be redirected to actually getting back to the Moon.

So what do we need to get people to the Moon and back? It turns out that, once liberated from the current Artemis architecture, NASA has a wealth of puzzle pieces to put together one or more lunar-return scenarios. The essentials need to come first: Landers and (if the astronauts are to go outside the lander) space suits.

4.2

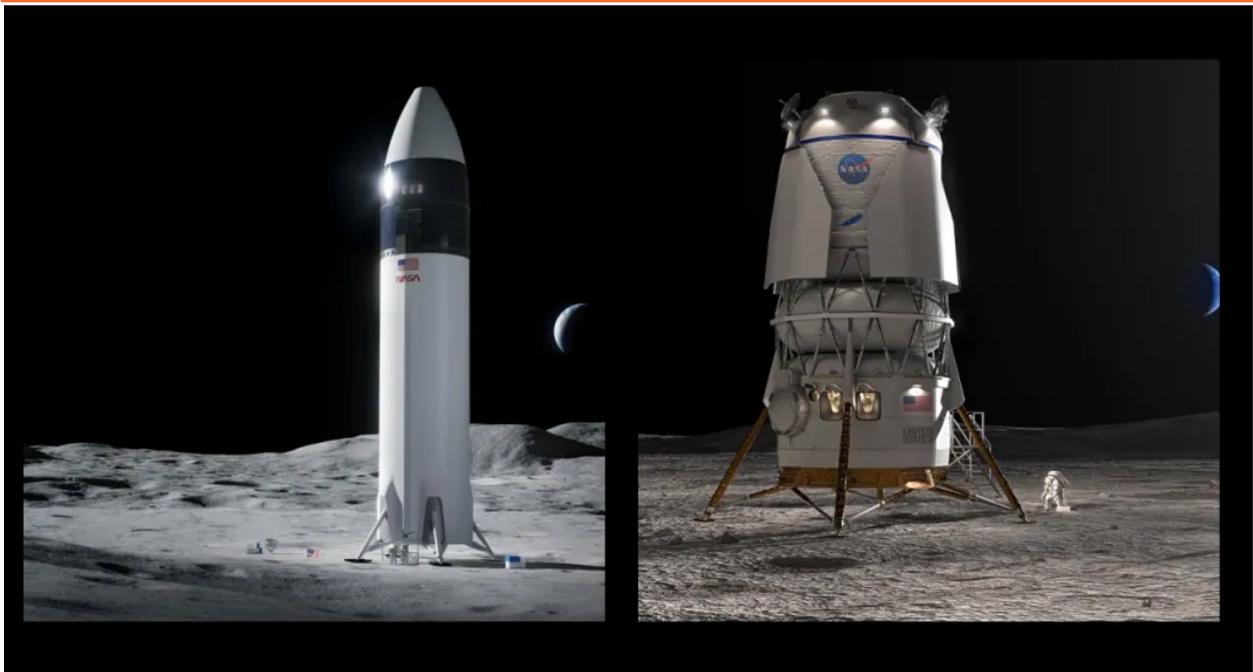
LANDERS AND SPACE SUITS

As already noted, it starts with the lander, because the lander drives the mass of everything else. It has to deliver the crew to the lunar surface from somewhere, and then return them to somewhere, which may or may not be the same place. As previously noted, the current plan is for that place to be Gateway in Near Rectilinear Halo Orbit (NRHO), but absent SLS, there are other possibilities. Apollo used low lunar orbit (LLO). LLO isn't stable for long durations, due to lunar mass concentrations that perturb it, but it would be satisfactory for short-duration missions (less than a month).

There are only two landers currently in NASA-funded development: the HLS version of Starship, and Blue Origin's Blue Moon. Blue Moon received \$4.3 billion in 2023, but its current planned schedule is for 2030, a date that would put in serious question the ability to get there before China. One could hope that China will be delayed, but as the old saying goes, hope is not a strategy.

Figure 7 shows HLS Starship and Blue Moon, which are the only landers currently being funded for Artemis. Starship, on the left, is much larger.

FIGURE 7: HLS STARSHIP AND BLUE MOON



Source: NASA <https://www.nasa.gov/humans-in-space/human-landing-system/>

The question is, if provided additional government funding, could that schedule be accelerated?

In the case of the fully reusable Starship, probably not, because SpaceX is already on the accelerator to get it ready for Mars, with its own money. It may not need to happen sooner than the current planned schedule, which is no earlier than 2027 for the Artemis III mission, because Starship HLS is probably not yet on the critical path, which is being delayed by SLS and Orion problems. But given the company's history with the Falcon family, which has now flown over 500 times and already had 50 flights in the first four months of 2025 alone, it is likely that once the problems with the past three failures are resolved, Starship progress will occur rapidly, because it is designed for rapid turnaround.

Blue Origin has announced that it expects to land the cargo version of Blue Moon in 2025.⁵⁹ So for Blue Moon, one would suspect that the answer is yes, if NASA will be accepting of risk by circumventing the questionable "human rating" process that for so long delayed Commercial Crew. And if it is, then it opens up the possibility of another provider coming up with one sooner, perhaps from one of the bidders who were not previously selected. As previously noted, it could be one with separate descent/ascent stages (like Apollo), which would reduce mass and perhaps make the design and development easier. It might have a "crasher" stage for most of the descent, then separate before landing, and then single stage for ascent (like the Chinese Lanyue lander). There are off-the-shelf hypergolic (nitrogen tetroxide oxidizer and hydrazine fuel) engines available from L3/Harris (which recently acquired Aerojet/Rocketdyne) with a long pedigree to quickly develop such a vehicle.⁶⁰ To decrease schedule risk, NASA could buy two different ones from two different bidders on fixed-price contracts with huge bonuses for early delivery and huge penalties for late delivery.

There is at least one other interesting solution: Use a Crew Dragon for the lander. As with the previous concept, it could have another vehicle take it most of the way down, then separate and crash, and the Crew Dragon would then be single-stage to LLO for the return to orbit. It would need legs, and it would probably transfer crew to a stock Dragon for the

⁵⁹ Jack Kuhr, "Blue Origin's 2025 Lunar Landing Goal," *Payload*, 6 March 2024. <https://payloadspace.com/blue-origins-2025-lunar-landing-goal/>

⁶⁰ "Hypergolic" means that the propellants ignite when they merely come in contact with each other and don't need an ignition source, making them more reliable. Not being cryogenic, they are also more storable, Matthew Fulco, "L3Harris Plays The Long Game With Aerojet Rocketdyne," *Aviation Week*, 19 September 2024. <https://aviationweek.com/aerospace/manufacturing-supply-chain/l3harris-plays-long-game-aerojet-rocketdyne>

trip back to Earth. Again, this would be impractical for sustained operations, but acceptable for the first few flights, to get there ahead of China.

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But the lander is the key element. Once it is defined, the job gets much easier, because there are a number of options for delivering it to its departure/arrival point.

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But the lander is the key element. Once it is defined, the job gets much easier, because there are a number of options for delivering it to its departure/arrival point. The next step is to determine how the crew will get back at least to LEO from that point, because the mass of that vehicle plus the mass of the lander determines the mass of the stage required to deliver them there. The return vehicle requires an on-orbit stage either with storable propellant while the crew are on the Moon (i.e., probably not liquid hydrogen), or the ability to be refueled before return.

Space suits are almost as essential as the lander for a useful mission. It would be pointless to send people to the lunar surface if they couldn't physically explore it. Fortunately, that problem seems to be well in hand. Axiom is working on a lunar suit under NASA contract, partnering with Prada, currently expected to be ready by 2026 (Figure 8), so it's not currently on the Artemis critical path.⁶¹ But it would be wise for NASA to take some of the savings from not flying SLS to fund a second space suit. Shown in Figure 9, SpaceX has already developed and tested some in space. They were worn by Jared Isaacman and his crew on the private Polaris Dawn mission in 2024 when they evacuated the SpaceX Dragon capsule for a spacewalk, and they reportedly worked well.⁶² The main problem with it is that it has no Portable Life-Support System (PLSS) backpack, so the two spacewalkers had to be on an umbilical to be provided with air and coolant. If NASA were to fund them to build a PLSS, they'd have a back up to the potential Axiom system. But if that development turned out to be on the critical path to a lunar return, the EVAs could be performed with

⁶¹ Jeff Foust, "Axiom and Prada unveil design of Artemis spacesuit" *Space News*, 16 October. 2024. <https://spacenews.com/axiom-and-prada-unveil-design-of-artemis-spacesuit/>

⁶² "Polaris Dawn Crew Tests New Suit and Completes First Commercial Spacewalk," Weblog, Polaris Program Blog, 12 September 2024. <https://polarisprogram.com/polaris-dawn-crew-tests-new-suit-and-completes-first-commercial-spacewalk/>

umbilicals as they were with Polaris Dawn, though the range from the lander would be extremely restrictive.

Figure 8 shows that Axiom Space has partnered with Prada to develop a lunar suit in time (theoretically) for Artemis III.

FIGURE 8: AXIOM SPACE LUNAR SUITS



Source: Space News/Jeff Foust <https://spacenews.com/axiom-and-prada-unveil-design-of-artemis-spacesuit>

SpaceX has developed and tested suits in orbit that could be used on the Moon, but they don't yet have a PLSS.

FIGURE 9: SPACEX TEST SUITS



Source: SpaceX <https://spacenews.com/spacex-reveals-eva-suit-design-as-polaris-dawn-mission-approaches/>

4.3

RETURN TO EARTH

The next question is: how do we get astronauts back to Earth from the rendezvous point?

One option is the current default: hope that the Orion heat shield problems are resolved and use it. But a lot of mass and cost could be saved if we could find an alternative. The most obvious one would be a SpaceX Crew Dragon, which is designed for long stays in space on the ISS. When it was in development, SpaceX claimed that its Phenolic Impregnated Carbon Ablator (PICA) thermal protection was designed to return from Mars, though it's not clear whether, in the process of "human rating" it by NASA, the shield material was reduced. But NASA could test the material in an uncrewed flight test to/from the Moon by tossing it to the Moon and around on a Falcon Heavy (it doesn't require crew to enter). If it can't, SpaceX could certainly beef it up. Because Crew Dragon has less lift/drag ratio than Orion, it might need to carry extra propellant to ensure a proper entry corridor, but there should be no major modifications needed. With a crew of only two, there would be ample cargo for consumables.

The ideal option, if Starship is going to be the lander, would be to simply send a Starship tanker out to the Moon for refueling, and then have it come all the way back. Again, since it is still in development simply for entry from LEO, this would require a test flight from the Moon, but it could simply be one of the many development flights that will be occurring in the next couple of years. Because it is being modified for lunar landing, it also may require further modifications to be able to land it back on Earth.

A variation on these could be a vehicle that doesn't take astronauts all the way back to Earth, but to LEO, at which point they could transfer to a Crew Dragon, or a Starship if it has shown the ability to enter from LEO but not from the Moon. In this case, the return could perhaps be performed by an upper stage, such as the Centaur V of the ULA Vulcan, or a Falcon Heavy upper stage, or the upper stage of Blue Origin's New Glenn. The Centaur and New Glenn vehicles use LOX/hydrogen, so they would have more propellant boil-off problems for the mission, relative to the SpaceX stage, which uses LOX/kerosene, but that is not a show-stopper.

PART 5

CONCLUSION AND RECOMMENDATIONS

5.1

CONCLUSION

First, and foremost, there is virtually no hope of getting back to the Moon before China while SLS continues. The resources currently being expended on SLS must immediately be transferred to a workable plan.

People will argue that we must keep the program going, because we have invested so many resources in the program. But this is a classic example of the sunk-cost fallacy: That we have wasted money on something in the past obligates us to continue to do so in the future, that we should indefinitely throw good money after bad. Obviously, the government can't un-spend money that it spent in the past, but Congress does have control of future expenditures and should finally seize it.

On February 26th of this year, Dr. Scott Pace, head of the Space Policy Institute at George Washington University, former director of the National Space Council in the first Trump administration, and long-time advocate for SLS, seemingly threw in the towel, testifying to Congress that it was time to find an "off ramp" for the program. He proposed flying Artemis II and Artemis III (the two flights that won't require the new MLP or upper stage), and then

shutting it down. NASA's initial FY 2026 budget outline calls for terminating SLS, et al, after those two missions.⁶³



Obviously, the government can't un-spend money that it spent in the past, but Congress does have control of our future expenditures and should finally seize it.



There are two problems with continuing with SLS. First, it means continuing to spend many billions of dollars per year on the program for as long as it takes to get those two flights completed. Second (and related), it increases the probability that the program will be stretched out. While the stated goal of the program was to employ the Shuttle workforce, there is already evidence from the criticism of Boeing that few people on that workforce are still on the program. The best approach would be to tear off the bandage immediately. To paraphrase Casey Handmer, the best time to cancel SLS (or its Constellation predecessor) was two decades ago, but that ship has long sailed. The second-best time is now.⁶⁴

There will be resistance to the cancellation, the most vociferous of which will be from the congressional delegations of the states most affected by it. For SLS, foremost will be Alabama, because the Marshall Space Flight Center in Huntsville is the primary center managing the SLS program, with Boeing as a major contractor there. If U.S. Space Command headquarters moves from Colorado Springs to Huntsville, as the Trump administration proposes, that would alleviate some of the pain, and there is still a lot of activity in the area from commercial companies, including SpaceX, Blue Origin, and United Launch Alliance (whose rocket factory is in nearby Decatur). The biggest effect on Kennedy Space Center would probably be the end of the work on ML-2, but there is no shortage of demand for launch pads both there and at Cape Canaveral Space Force Station, so the effect on the Space Coast economy would probably be minimal. It will also affect Michoud

⁶³ Joey Roulette, "Trump 2026 Space Budget Would Cancel NASA Rocket, Lunar Station," Reuters, 2 May 2025.

⁶⁴ Casey Handmer, "SLS is still a national disgrace," Weblog post, Casey Handmer's Blog, 2 October 2024. <https://caseyhandmer.wordpress.com/2024/10/02/sls-is-still-a-national-disgrace>

in southeast Louisiana, where the core stage is manufactured. Michoud could perhaps be turned to manufacturing large modules for future space facilities, perhaps even for commercial ones, if it can be cost competitive. Though it does not have a NASA center, one other state that may push back against SLS cancellation will probably be Utah, because Northrop Grumman's facility in Promontory pours the segments for the solid rocket boosters there. But there is sufficient demand for solid rockets from the Air Force for their ICBMs and other missiles, and to a lesser degree from ULA for its Vulcan rockets, that the facility will continue to have ample business without SLS. Another non-NASA state that will push back will be Colorado, where Orion is built in a Denver suburb, but there is ample growing space business, particularly commercial, in the Front Range that it will not be a major blow to the region.

At some point, Congress may have to establish a commission for a Base Realignment and Closure (BRAC) for the space agency, as occurred with the Pentagon after the end of the Cold War, but such considerations are far beyond the scope of this vision paper.

But Congress needs to initiate studies to determine the best path forward. It's possible that internal teams at NASA have already been doing this since the election. In his latest article at *The New Atlantis*, Robert Zubrin has a suggestion as to how to ensure the proper incentives (though this is about getting to Mars, it is equally applicable to getting back to the Moon):

The first requirement to get the...effort started right is to create a competent program leadership. A Tiger Team needs to be established within NASA composed of technically excellent people who understand the purpose of the program and whose first loyalty is to the mission. The program cannot be led properly by people who are representing outside interests such as various technology development programs, aerospace companies, or NASA centers who are looking for a piece of the action. The program will undoubtedly need the services of many such entities, but they are vendors to the program, not the purpose of the program. You don't run a company in order to deliver cash to vendors. You pay vendors in order to pursue the purposes of the company. If it is to succeed, the program must be purpose-driven, not vendor-driven. [Emphasis added]⁶⁵

⁶⁵ Robert Zubrin, "The Mars Dream Is Back – Here's How To Make It Actually Happen," *The New Atlantis*, 31 January 2025 <https://www.thenewatlantis.com/publications/the-mars-dream-is-back-how-to-go>

5.2

RECOMMENDATIONS

Simultaneously, public policy must be restructured to unleash private industry on cislunar space, and ultimately, the solar system within the decade. The Department of Defense has already recognized the need to drastically streamline procurement, and NASA must follow the lead. Beyond that, some of the savings from ending the programs above should be redirected to getting NASA back to its initial role of researching technology to meet commercial needs, in partnership with industry, just as its predecessor, the National Advisory Committee on Aeronautics (NACA) did in the first half of the 20th century for aviation. Commercial Crew and Cargo have pointed the way to public/private partnerships for both technology maturation and the development of competitive commercial programs for the provision of transportation and habitation for both government and commercial needs.

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Regulations that hinder progress must be pared back. In particular, environmental regulations that have been holding back (for example) flight testing of Starship in Texas must be eased. When the National Environmental Policy Act (NEPA) was passed in 1970, it led to categorical exclusions for the aviation industry because lawmakers understood that if this didn't happen the industry would founder.⁶⁶ At the time, space was not an issue, because all space activities were governmental, which were already exempt from NEPA. But today, commercial space is at a disadvantage because it does have to follow the law. This resulted in an absurd situation, in which general aviation aircraft could fly in and out of Mojave Air and Spaceport daily, as with any other general-aviation airport, but if the airplane had a rocket engine (as XCOR Aerospace's EZRocket did), the runway, at least in theory, had to be patrolled for endangered desert tortoises before takeoff. For the long-standing commercial airport in Midland, Texas to become a spaceport, it first had to do an Environmental Impact Statement on the potential effects on the prairie chicken. Now that

⁶⁶ “Categorical Exclusions,” Federal Aviation Administration, Department of Transportation, www.faa.gov/airports/central/environmental/catex

commercial space activities are starting to dominate those of the government, it would make sense to at a minimum extend those aviation exclusions to space.

The Office of Commercial Space Transportation (OCST), which regulates commercial launch activities, should be taken out from under the Federal Aviation Administration (FAA), where it was mistakenly placed over three decades ago during the Clinton administration, as part of “streamlining government.” It was originally reporting directly to the secretary of transportation, and it should be returned to that position. The safety cultures of the FAA and the nascent commercial spaceflight industry are incompatible, in that the FAA has a responsibility to ensure that airline passengers are safe to a degree far beyond what is currently feasible for commercial spaceflight. Airlines have to cater to a range of customers with a widely varying tolerance of risk. Innovation and opening frontiers require tolerance of informed risk or it will become moribund (as has happened with general aviation). This would not require legislation, because OCST was originally put under the FAA by executive order, and could be moved back the same way.



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The U.S. government has an obligation under Article VI of the 1967 Outer Space Treaty to provide “continuing supervision” of its persons engaged in space activities. OCST has performed this function for launch operations since the passage of the Commercial Space Launch Act in 2004, but no federal entity is currently designated by the agency for doing this for U.S. space activities, including space traffic control. There has been competition for the role of “mission authorization” between DOT and the Department of Commerce for several years.

Much of what has to be “supervised” off planet has nothing to do with transportation, and given that it is commercial activity, that responsibility should reside at the DOC for now, but it will require a significant expansion of the Office of Space Commerce (to which NOAA

should report, rather than the reverse, which has historically been the case). It will have to deal with space situational awareness and monitoring/warning about conjunctions of the now thousands of satellites in Earth orbit to avoid collisions. It will also have to work in concert with industry to develop standards (think of them as “building codes”) for space habitats. It is in an ideal position to do this, with the National Institute of Standards and Technology (NIST), and in coordination with other standards organizations, such as the American Society of Mechanical Engineers (ASME), the American National Standards Institute (ANSI), ASTM International, the American Institute for Aeronautics and Astronautics (AIAA), the Institute of Electrical and Electronics Engineers (IEEE), and others.

Congress should consider establishing a U.S. Space Guard (a space equivalent of the Coast Guard), to manage navigation (the USCG was originally lighthouses), constabulary duties, and search/rescue, duties that should be civilian, rather than provided by the U.S. Space Force. It would be a civilian but uniformed service with an academy, and attached to the Space Force in war, as the Coast Guard is to the Navy. The reductions of launch cost both in the recent past, and even more dramatically to come, will enable the affordable development of actual military space bases in both low Earth orbit and other locations in cislunar space from which both the Space Force and Space Guard could operate. The Coast Guard is currently under the Department of Homeland Security (part of the mistake made when DHS was created two decades ago) but the Space Guard should be under DoC, because it will be a vital part of the Outer Space Treaty Article VI obligations. Commercial space pioneer and historian James C. Bennett described the concept in detail 14 years ago.⁶⁷

A quarter of the way into the 21st century, we need to end the antiquated thinking of space as a “mission” or as “research.” Space is a place, and an unimaginably immense one, in which the vast majority of energy and material resources in the solar system can be found. It is a place in which hundreds, then thousands, then millions of people will be living, working, and playing in the coming decades. We need to establish policy that will finally, almost seven decades after our first satellites, treat space as a place, and ensure that those values will be carried out into the solar system.

⁶⁷ James C. Bennett, “Proposing a ‘Coast Guard’ for Space,” *The New Atlantis*, Winter 2011, <https://www.thenewatlantis.com/publications/proposing-a-coast-guard-for-space>

ABOUT THE AUTHOR

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Mr. Simberg holds multiple engineering degrees from the University of Michigan, Ann Arbor and a Master's degree in technical management from West Coast University in Los Angeles. He is a former adjunct scholar with the Competitive Enterprise Institute, and has written many pieces for *Popular Mechanics*, Fox News, *America Online*, *PJMedia*, *National Review*, *Reason* magazine, *The Weekly Standard*, *The Washington Times*, and *TCSDaily*, among others. He has also written extensive essays on space policy and technology for the quarterly journal, *The New Atlantis*. He 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.*"

