Beyond Earth: Deep Research on the Most Important Breakthroughs and News in Space and Aerospace from the Past 7 Days

Introduction: The Week's Trajectory – Building the Extraterrestrial Economy

The past seven days in the space and aerospace sector have been characterized by a series of pivotal advancements that, while diverse in nature, converge on a singular, overarching theme: the concerted construction of a permanent and sustainable human economic sphere beyond Earth. The week's developments are not isolated events but interconnected components of a broader strategic pivot. We are witnessing a deliberate push to establish the foundational pillars of a self-sustaining off-world economy, a push driven by escalating geopolitical imperatives and enabled by disruptive manufacturing and operational technologies.

Three dominant trends have emerged. First, geopolitical acceleration is now an explicit driver of space policy. The framing of lunar development as a "new space race" by senior U.S. officials is directly influencing timelines and funding priorities for critical infrastructure, most notably for power generation on the Moon.[1] Second, an industrial revolution is taking shape in space technology. Breakthroughs in large-scale additive manufacturing and collaborative robotics signal a fundamental shift away from bespoke, artisanally crafted space hardware toward scalable, automated, and cost-effective production and operational models.[3] Finally, the symbiotic relationship between public agencies and private enterprise is solidifying into a new operational paradigm. Government bodies are increasingly acting as strategic architects and anchor tenants, relying on commercial partners to develop, own, and operate core capabilities, from lunar power systems to orbital habitats.[5] This report will provide an exhaustive analysis of these key developments, their underlying challenges, and their profound implications for the future of humanity's expansion into the cosmos.

Table 1: Executive Summary of Key Weekly Advancements		
Technology/Event	**Lead Entities**	**Core Strategic Implication**
NASA Lunar Reactor Directive	NASA, U.S. Commercial Sector	Establishes energy independence as the primary enabler for sustainable lunar presence and a key instrument in geopolitical competition with China and Russia.[1]
Agnikul Cosmos Engine Patent	Agnikul Cosmos (India)	Validates single-piece additive manufacturing as a disruptive force in rocket propulsion, challenging established supply chains and democratizing access to space.[3]
Firefly Aerospace IPO	Firefly Aerospace, Northrop Grumman	Signals strong investor confidence in a multi-polar commercial launch market and validates the business case for commercially provided lunar landing services.[5]
JAXA/DLR Robot Collaboration	JAXA (Japan), DLR (Germany)	Demonstrates the first successful interoperability between disparate national robotic systems, a critical milestone for future international collaboration on in-space assembly and maintenance.[4]

Key Technological Breakthroughs: The New Industrial Revolution in Space

This week witnessed two landmark technological demonstrations that represent a paradigm shift in how the tools for space exploration are built and operated. These are not incremental improvements but foundational changes that promise to accelerate the pace and reduce the cost of off-world activities, heralding a new industrial era for the space sector.

Additive Manufacturing at Scale: Agnikul Cosmos's Single-Piece Engine

A transformative development in propulsion technology emerged from Indian startup Agnikul Cosmos, which unveiled the world's largest single-piece 3D-printed rocket engine.[3] This component, fabricated from Inconel—a high-performance, nickel-chromium superalloy renowned for its strength and resistance to extreme temperatures—is approximately one meter in length. Its most revolutionary characteristic is that it is printed as a single, monolithic component, entirely eliminating the need for welds, joints, or fasteners from the fuel injector to the nozzle exit.[9]

This "fully integrated manufacturing approach" radically simplifies what is traditionally a highly complex assembly process. By obviating the need to weld or bolt together hundreds of individual parts, this method is reported to reduce overall production time by more than 60% and significantly decrease engine weight.[3] More critically, it removes countless potential failure points inherent in joints and welds, thereby increasing the engine's intrinsic reliability. Agnikul describes this as the "automation of the entire process of manufacturing a rocket engine as a single unit," a profound departure from legacy methods.[10]

The strategic importance of this achievement was amplified by the granting of a U.S. patent for the design and manufacturing process.[3] Securing this intellectual property protection in the world's most competitive aerospace market provides a powerful international validation of an Indian-origin design. It signals the emergence of India's private space sector as a formidable global competitor in next-generation propulsion technologies.[10] This patented engine, named Agnilet, is the core propulsion system for Agnikul's Agnibaan launch vehicle, a small-lift rocket designed to deliver a 100 kg payload to a 700 km low Earth orbit, targeting the burgeoning small satellite market.[12]

The immediate consequence of this development is a profound disruption of the terrestrial aerospace supply chain, a necessary precursor to any future in-space manufacturing paradigm. The ability to design, print, test, and iterate a complex rocket engine in a fraction of the time and cost associated with traditional methods creates immense competitive pressure on legacy manufacturers, who rely on intricate, multi-tiered global supply chains. This agility favors newer, more vertically integrated startups and may force widespread technological adoption or consolidation among established industry giants. The on-demand nature of this production model represents a fundamental change in aerospace logistics. This terrestrial manufacturing revolution is not only significant in its own right but also serves as an essential blueprint for eventual in-space manufacturing, which will undoubtedly leverage similar principles of automation, single-piece construction, and advanced materials to build and repair systems far from Earth.[3]

The Dawn of Collaborative Robotics: JAXA and DLR's "ICHIBAN" Mission

A second major breakthrough occurred aboard the International Space Station (ISS), where the Japan Aerospace Exploration Agency (JAXA) and the German Aerospace Center (DLR) conducted the "ICHIBAN" mission—the first-ever successful in-orbit collaboration between two independently developed robotic systems.[4] The mission involved Germany's Crew Interactive Mobile Companion (CIMON), an AI-powered astronaut assistant, and Japan's Int-Ball2, a free-flying camera drone.[4]

The experiment provided a compelling demonstration of advanced human-robot teaming. From the European Columbus module, JAXA astronaut Takuya Onishi issued a simple voice command to CIMON.[4] The AI-driven systems within CIMON, which leverage IBM's watsonx platform, correctly interpreted the command, translated it into machine-readable instructions, and transmitted them to the Int-Ball2 drone, which was located in the separate Japanese Kibo experiment module.[4] Following these remote instructions, Int-Ball2 autonomously navigated to locate several target objects, including a Rubik's Cube and tools, and streamed its video feed back to CIMON's screen, allowing the astronaut to supervise the task's completion from a different part of the station.[4]

The technological significance of this mission cannot be overstated. It successfully established a common interface that allowed robots from different national agencies, with entirely separate hardware and software ecosystems, to communicate and cooperate in real-time to achieve a shared goal.[4] This proves the viability of a distributed, multi-agent robotic system managed by a single human operator through a natural language interface, a concept that is critical for future complex operations like constructing and maintaining outposts on the Moon and Mars.[18]

This achievement points toward a future operational model for large-scale international space projects. The primary challenge in endeavors like building a lunar base is not only technical but also organizational, involving multiple partners who each bring their own proprietary technologies. The ICHIBAN experiment demonstrates that a common, AI-driven interface can serve as a "universal translator" or middleware layer, abstracting the control complexities of disparate robotic systems. This creates a pathway for a "plug-and-play" ecosystem of international robotic assets. Instead of requiring all partners to adopt a single, monolithic hardware standard—a politically and financially prohibitive task—nations can develop specialized robotic systems optimized for specific tasks, provided they can interface with a common operational framework. This model dramatically lowers the barrier to entry for international collaboration, enabling a more agile and efficient approach to building complex infrastructure beyond Earth.[20]

Mission and Commercial Developments: The Maturing Cislunar Economy

The commercial space sector demonstrated increasing maturity and financial momentum this week, highlighted by a major public offering and a continued high tempo of launch operations that underscore the growing demand for in-space services.

Firefly Aerospace's IPO: A New Public Heavyweight Enters the Arena

Firefly Aerospace made a resounding debut on the public market, raising approximately $868 million in its Initial Public Offering on the Nasdaq exchange.[5] The company sold over 19 million shares at $45 each, significantly above its initial price range, giving it a market capitalization exceeding $8 billion.[5] This event marks the largest U.S. space technology IPO of the year and reflects strong investor confidence in the emergence of new, credible players in the launch and in-space services market.[5]

This robust market reception is not based on speculation alone; it is anchored by Firefly's tangible technical accomplishments. Critically, the company is only the second private firm in history to achieve a successful soft landing on the Moon, a feat accomplished with its Blue Ghost lander in March 2025.[5] This demonstrated capability provides a crucial layer of credibility that differentiates it from many other aspiring space ventures.

Firefly's business model is focused on the small-to-medium launch market with its Alpha rocket, as well as a suite of in-space services that include its forthcoming Eclipse rocket, the Elytra orbital vehicle, and its proven lunar lander platform.[5] The company's strategic position is fortified by a contract backlog valued at over $1.1 billion, which includes key agreements with NASA and the U.S. Space Force.[5] A recent $50 million investment from defense prime Northrop Grumman further cements its role within the national security space ecosystem.[5] While the company currently operates at a net loss due to significant R&D expenditures, its proven technology and strong contractual foundation present a clear and credible path toward future profitability.[5]

The Workhorses of LEO: Sustaining the Launch Cadence

The past week also saw a continued, rapid cadence of launches to low Earth orbit, primarily in service of building out massive satellite constellations. In a notable mission, SpaceX used a Falcon 9 rocket to deploy a batch of 24 of Amazon's Project Kuiper broadband satellites.[22] This was the second dedicated launch that Amazon has booked with its chief competitor, SpaceX, to accelerate the build-out of its planned 3,200-satellite constellation, which aims to rival Starlink.[22]

In the small satellite domain, Rocket Lab conducted its 11th Electron launch of 2025, successfully deploying the QPS-SAR-12 satellite for Japan's iQPS synthetic-aperture radar (SAR) constellation.[23] This mission highlights the persistent and healthy demand within the dedicated small satellite launch sector and demonstrates Rocket Lab's ability to maintain an increased launch tempo.

Meanwhile, human spaceflight operations proceeded with routine efficiency. The regular crew rotation at the ISS continued with the arrival of the Crew-11 mission and preparations for the departure of Crew-10, both facilitated by SpaceX's Dragon capsules.[25] These missions underscore the operational maturity of NASA's Commercial Crew Program, which now serves as the United States' sole method for transporting astronauts to orbit. This reliance on SpaceX has been further entrenched by the ongoing grounding of Boeing's Starliner spacecraft until at least 2026, which has forced NASA to reassign its astronauts to SpaceX flights and has solidified SpaceX's de facto monopoly on U.S. crew transport for the foreseeable future.[25]

These commercial developments reveal a market that is beginning to bifurcate into two distinct investment models, mirroring the structure of more mature industries like aviation or automotive. On one hand, companies like Firefly are positioning themselves as integrated "prime contractors." Firefly develops the launch vehicle, the orbital transfer vehicle, and the lunar lander, allowing it to bid on and execute end-to-end missions for government and commercial customers.[5] Investors in Firefly are backing a vertically integrated, "SpaceX-lite" business model. On the other hand, a company like Agnikul Cosmos is emerging as a disruptive "component supplier." Its core value proposition is its revolutionary 3D-printed engine, a technology that can be sold to other launch providers or used in its own rockets.[3] This suggests investors can now choose between backing full-service providers or hyper-specialized technology firms that supply the entire industry.

At the same time, SpaceX's dominance in the launch sector is creating a paradoxical market dynamic. It is simultaneously the greatest enabler and the most significant competitor for new space ventures. The fact that Amazon must rely on SpaceX's Falcon 9 to launch its competing Kuiper constellation is a stark illustration of this reality.[23] In doing so, Amazon is directly funding its rival's launch division, contributing to the very economies of scale that make SpaceX's position so formidable. This codependency highlights a critical market bottleneck in heavy-lift launch, creating a fragile and complex ecosystem that will likely persist until alternative vehicles like Blue Origin's New Glenn or ULA's Vulcan become fully operational and demonstrate a comparable flight record.

Space Infrastructure: Laying the Foundation for Permanent Outposts

This week's most significant developments centered on the foundational infrastructure required for a permanent human presence beyond Earth. New government directives have dramatically accelerated plans for both lunar power generation and the development of commercial space stations in low Earth orbit, signaling a strategic urgency to build the next generation of off-world outposts.

The Lunar Power Grid: NASA's Accelerated Nuclear Fission Reactor Program

In a major policy shift, acting NASA Administrator Sean Duffy issued a directive to fast-track the development and deployment of a nuclear fission reactor on the Moon, establishing an aggressive target date of 2030.[1] This new plan represents a significant escalation of previous efforts. It scraps earlier concepts for a 40-kilowatt reactor and instead calls for industry to propose systems capable of generating 100 kilowatts of electrical power.[2] This substantial increase in power output is deemed essential for enabling industrial-scale activities, particularly in-situ resource utilization (ISRU) for producing propellants and breathable air from lunar ice, as well as for supporting multiple crew habitats simultaneously.[7]

The timing and scale of this initiative are explicitly driven by geopolitical competition. The directive is framed as a direct response to the "new space race," aimed at outpacing a joint China-Russia plan to establish their own lunar research station, potentially with its own nuclear power source.[1] U.S. officials have voiced concerns that the first nation to establish a reliable power grid on the Moon could declare a large "keep-out zone" for safety reasons, which could function as a de facto claim on strategically valuable territory, such as the resource-rich polar regions.[2]

The procurement model mandated by the directive is heavily reliant on the private sector. NASA is instructed to appoint a project lead and solicit industry proposals within 60 days, with the goal of funding at least two competing companies to design, build, and integrate their reactors with a lunar lander.[1] This approach turns the lunar power grid into a major test case for NASA's strategy of procuring critical deep-space infrastructure as a commercial service.

Post-ISS Architecture: NASA's Revised Commercial LEO Destination Strategy

A second crucial infrastructure directive emerged, revealing a significant change in NASA's acquisition strategy for the commercial space stations intended to succeed the ISS after its planned decommissioning around 2030.[29] NASA is pivoting away from its original plan to use traditional, firm-fixed-price government contracts for the second phase of its Commercial LEO Destinations (CLD) program. Instead, the agency will utilize multiple funded Space Act Agreements (SAAs).[30] This shift provides greater design and development flexibility for the commercial partners and for NASA, but it also transfers more of the financial risk to the companies. Formal system certification, a rigorous process to ensure astronaut safety, will now be pushed to a subsequent, separate procurement phase.[30]

This revised strategy is designed to maintain a competitive and diverse industrial base. The current CLD landscape includes several key players, each with a different approach.

Table 2: Comparative Analysis of Commercial LEO Destination Contenders				
Company/Venture	**Station Name**	**Core Technology/Design Concept**	**Funding Status & NASA Relationship**	**Projected First Launch**
Axiom Space	Axiom Station	Modules attached to ISS, later detaching to form a free-flying station.	NASA contract for module integration; revenue from private astronaut missions.	First module launch is near-term. [31]
Vast	Haven-1 / Haven-2	Single-module spinning station providing artificial gravity;	Privately funded; unfunded NASA CLD partner.	Haven-1 planned for NET May 2026. [32]

		later a multi-module station.	Seeking Phase 2 funding.	
Blue Origin / Sierra Space	Orbital Reef	Large-volume, expandable modules designed as a "mixed-use business park."	Funded NASA CLD Phase 1 SAA partner.	Timeline dependent on Phase 2 awards.[30]
Starlab Space (Voyager/Airbus)	Starlab	Single-launch, metallic-structure free-flyer with inflatable habitat elements.	Funded NASA CLD Phase 1 SAA partner.	Timeline dependent on Phase 2 awards.[30]

These dual directives, when viewed together, signal a fundamental, agency-wide philosophical evolution. NASA is consciously moving from its historical role as a "developer" of space systems to a new role as a "strategic acquirer" of space infrastructure and services. The lunar reactor plan outsources the entire design-and-build process to commercial entities, with NASA setting top-level requirements and managing the competition.[7] Similarly, the revised CLD strategy shows a desire to procure services from a mature, competitive market rather than micromanaging the development of specific station designs.[30] This represents the full realization of the public-private partnership model that began with the Commercial Cargo and Crew programs, extending it now to the core infrastructure of human activity in both LEO and cislunar space.

Furthermore, the hard 2030 deadline for both the ISS replacement and the lunar reactor acts as a powerful forcing function. This convergence creates immense pressure on budgets and the industrial base, but it also makes legacy, multi-decade development programs untenable. The risk is that one or both of these critical initiatives could fail due to aggressive timelines and insufficient funding, leaving the U.S. with a gap in orbital presence and falling behind in the race for the Moon. The opportunity, however, is that this intense pressure could catalyze a "wartime" cycle of innovation, fundamentally accelerating the pace of space development and forcing the adoption of faster, more agile commercial models. The 2030 deadline is therefore not just a date, but a potent strategic instrument.

Challenges and Considerations: Navigating the Path Forward

The ambitious plans advanced this week are accompanied by formidable technical, safety, and geopolitical challenges that must be addressed to ensure their success. The development of a lunar nuclear reactor, in particular, highlights the immense hurdles that lie on the path to establishing a permanent off-world presence.

The Nuclear Option: A Sober Look at Technical and Safety Hurdles

The proposal to deploy a 100-kilowatt nuclear reactor on the Moon by 2030 faces several critical technical obstacles. The most significant of these is heat rejection. In the vacuum of the lunar environment, where there is no air or water for conventional cooling, a reactor must radiate all its waste heat directly into space.[2] This requires large, heavy radiator panels, which add substantial mass and complexity to the lander payload and are vulnerable to performance degradation from coatings of abrasive lunar dust.[35] The sheer scale of the radiator farm needed to dissipate the thermal load from a 100 kW system could become a dominant factor in the design and cost of the entire mission.

This ties directly to the challenge of mass and power density. The original 40-kilowatt Fission Surface Power (FSP) concepts were already pushing the mass limits of a 6-metric-ton lunar lander.[35] More than doubling the power output to 100 kW while keeping the total mass of the reactor, its radiation shielding, and its cooling system within the payload capacity of existing or near-term landers is a monumental engineering task.[7]

Finally, safety considerations are paramount. While the reactor would be launched in a "cold" or unirradiated state to minimize risk, a launch failure still carries the potential for dispersing uranium fuel into the atmosphere or environment.[34] An even more complex long-term issue is the end-of-life decommissioning of the reactor. Once operational, the fuel becomes highly radioactive. The safe, permanent disposal of this spent fuel on the Moon, or the even riskier proposition of returning it to Earth, presents a major safety and environmental challenge. The specter of an uncontrolled reentry of highly radioactive material, as occurred with the Soviet Kosmos 954 satellite in 1978, looms over any plan for nuclear power in space.[34]

Geopolitical and Regulatory Headwinds

The aggressive push for lunar infrastructure also creates significant geopolitical and legal challenges. The 1967 Outer Space Treaty, the bedrock of international space law, explicitly prohibits the national appropriation of celestial bodies "by claim of sovereignty, by means of use or occupation, or by any other means." The new directive's explicit mention of establishing "keep-out zones" around a lunar reactor puts this principle under immense strain.[1] While such zones would be justified on the grounds of operational safety, they could easily be perceived by other nations as de facto territorial claims, potentially triggering international disputes and undermining the cooperative framework of the treaty.[35]

These ambitious programs are also running headlong into budgetary realities. The accelerated timelines for both the lunar reactor and the commercial LEO stations are being set against a backdrop of flat or potentially declining NASA budgets.[1] There is a substantial risk that these flagship infrastructure projects are being initiated without sufficient funding, which could lead to severe delays, compromise safety, or force NASA to cannibalize its other critical programs, such as Earth science and robotic exploration, to pay for them.[35]

Future Outlook: Strategic Implications and Near-Term Implementations

The technological breakthroughs and strategic directives of the past week provide a clear vector for the future of space exploration and development. The trends in manufacturing, robotics, and infrastructure are setting the stage for a transformative decade.

The Factory of the Future: From Terrestrial Disruption to In-Space Production

In the near term, over the next one to three years, the maturation of technologies like Agnikul's single-piece 3D-printed engine will continue to disrupt terrestrial aerospace manufacturing.[3] Expect wider adoption of large-format additive manufacturing across the industry as both startups and legacy primes seek to cut costs, shorten lead times, and reduce supply chain complexity.[42] This will lower the barrier to entry for new launch providers and make access to space more affordable, further fueling the growth of the LEO satellite economy.

Looking further ahead to the next five to ten years, the expertise gained from automating terrestrial production will serve as the direct blueprint for developing robust in-space manufacturing (ISM) capabilities.[14] The initial applications of ISM will likely focus on producing on-demand spare parts, custom tools, and simple structural components aboard orbital platforms or on the lunar surface. This will reduce the costly dependence on resupply missions from Earth. The ultimate goal, however, is to leverage in-situ resources—using lunar regolith or Martian soil as feedstock for 3D printers—to construct large-scale infrastructure such as habitats, radiation shields, and landing pads, enabling a truly self-sufficient off-world presence.[14]

The Robotic Co-Worker: The Path to Autonomous Construction

The successful ICHIBAN experiment paves the way for more advanced human-robot teaming demonstrations in the near term.[4] Over the next few years, expect to see increasingly complex, multi-agent robotic operations on the ISS and in terrestrial analog environments. The focus will be on refining AI-driven control interfaces and expanding the "plug-and-play" interoperability between different robotic systems, using platforms like NASA's Astrobee and DLR's Rollin' Justin to tackle more sophisticated tasks.[19]

In the long term, the objective is to evolve from direct human-robot collaboration to the deployment of semi-autonomous robotic teams capable of performing large-scale construction, maintenance, and resource extraction on the Moon and Mars with only high-level human supervision.[19] This capability is essential for the concept of "pre-deployment," where robotic systems prepare habitats, power grids, and other critical infrastructure

before the first human crews arrive. This approach dramatically enhances mission safety and efficiency, making long-duration stays on other worlds viable.[46]

The Geopolitics of Cislunar Space: The Primacy of Power and Position

The race to establish a functional lunar power grid by 2030 will become the central organizing principle of national space strategies for the rest of this decade.[28] Access to continuous, high-output energy is the fundamental gateway to all other long-term lunar ambitions, including permanent habitation, industrial-scale resource utilization, and a sustained scientific and potentially military presence.[28]

Consequently, strategic competition will intensify, focusing on securing optimal locations on the Moon—primarily the polar craters, which are believed to hold deposits of water ice and may offer access to "peaks of eternal light" for supplemental solar power. The establishment of critical infrastructure, especially nuclear reactors, will force intense diplomatic and legal debate over the interpretation of the Outer Space Treaty. The United States and the emerging China-Russia bloc are likely to develop divergent norms of behavior regarding safety zones, resource rights, and operational transparency.[36] The coming years will be defined by a race to create "facts on the regolith"—to build and operate infrastructure that will shape the legal, political, and economic landscape of the Moon for generations to come.

Works cited

1. New space race: Acting Nasa chief Duffy to announce plan for building nuclear reactor on moon this week- Here's what we know, accessed August 8, 2025, https://timesofindia.indiatimes.com/world/us/new-space-race-acting-nasa-chief-duffy-to-announce-plan-for-building-nuclear-reactor-on-moon-this-week-heres-what-we-know/articleshow/123107077.cms
2. NASA plans to put a nuclear reactor on the moon. Here's what that means - KPBS, accessed August 8, 2025, https://www.kpbs.org/news/science-technology/2025/08/08/nasa-plans-to-put-a-nuclear-reactor-on-the-moon-heres-what-that-means
3. Indian space startup Agnikul builds world's largest single-piece 3D-printed Inconel rocket engine, granted a patent in US, accessed August 8, 2025, https://timesofindia.indiatimes.com/science/indian-space-startup-agnikul-builds-worlds-largest-single-piece-3d-printed-inconel-rocket-engine-granted-a-patent

-in-us/articleshow/123163895.cms
4. Germany and Japan teamed their ISS robots - The Register, accessed August 8, 2025, https://www.theregister.com/2025/08/05/germany_and_japan_teamed_their/
5. fly stock: Firefly Aerospace ignites Wall Street as it raises $868 ..., accessed August 8, 2025, https://economictimes.indiatimes.com/news/international/global-trends/us-news-firefly-aerospace-ignites-wall-street-as-it-raises-868-million-in-biggest-space-ipo-all-about-spacex-rival/articleshow/123168763.cms
6. NASA Releases Opportunity to Boost Commercial Space Tech Development, accessed August 8, 2025, https://www.nasa.gov/directorates/stmd/nasa-releases-opportunity-to-boost-commercial-space-tech-development/
7. NASA Wants To Hit the Accelerator On Lunar Atomics - Payload, accessed August 8, 2025, https://payloadspace.com/nasa-wants-to-hit-the-accelerator-on-lunar-atomics/
8. Space Tech Firm Firefly's Stock Pops in Its Trading Debut - Investopedia, accessed August 8, 2025, https://www.investopedia.com/space-tech-firm-firefly-stock-pops-in-trading-debut-11786884
9. Agnikul Cosmos 3D prints largest single-piece Inconel rocket engine | VoxelMatters, accessed August 8, 2025, https://www.voxelmatters.com/agnikul-cosmos-3d-prints-largest-swingle-piece-inconel-rocket-engine/
10. Agnikul Cosmos unveils world's largest single piece 3D printed rocket engine, secures US patent - Business Today, accessed August 8, 2025, https://www.businesstoday.in/technology/news/story/agnikul-cosmos-unveils-worlds-largest-single-piece-3d-printed-rocket-engine-secures-us-patent-488299-2025-08-07
11. Agnikul Cosmos Unveils World's Largest Single-Piece 3D-Printed Rocket Engine, Secures US Patent | Indian Defence News, accessed August 8, 2025, https://www.indiandefensenews.in/2025/08/agnikul-cosmos-unveils-worlds-largest.html
12. Agnibaan - Wikipedia, accessed August 8, 2025, https://en.wikipedia.org/wiki/Agnibaan
13. Agnikul Cosmos - Technology Pioneers, accessed August 8, 2025, https://initiatives.weforum.org/technology-pioneers/organization-details/agnikul-cosmos/0016800000TsjsWAAR
14. 3D Printing & the Future of Space Exploration | Cutter Consortium, accessed August 8, 2025, https://www.cutter.com/article/3d-printing-future-space-exploration
15. JAXA and German Aerospace Centre achieve world-first in ISS robotic collaboration, accessed August 8, 2025, https://www.spaceconnectonline.com.au/r-d/6626-jaxa-and-german-aerospace-centre-achieve-world-first-in-iss-robotic-collaboration

16. Mission ICHIBAN: Robotic Cooperation Takes Flight on the ISS - ActuIA, accessed August 8, 2025, https://www.actuia.com/en/news/mission-ichiban-robotic-cooperation-takes-flight-on-the-iss/
17. One Step Before Robotic Control?: Two AI systems carried out a conversation on the ISS | Israel National News, accessed August 8, 2025, https://www.israelnationalnews.com/news/412541
18. Germany and Japan Tested Robot Astronauts on the ISS For Future Space Missions, accessed August 8, 2025, https://orbitaltoday.com/2025/08/05/germany-and-japan-tested-robot-astronauts-on-the-iss-for-future-space-missions/
19. Robotics in Space Exploration: Transforming Missions from Mars to the Moon and Beyond, accessed August 8, 2025, https://www.automate.org/news/-122
20. Who's a good robot dog? Bert and Spot explore Mars-like surface with help from AI and astronaut in space, accessed August 8, 2025, https://www.space.com/space-exploration/mars-rovers/whos-a-good-robot-dog-bert-and-spot-explore-mars-like-surface-with-help-from-ai-and-astronaut-in-space
21. The Future of Human-Robot Interaction Is Mobile | Magazine | Northwestern Engineering, accessed August 8, 2025, https://www.mccormick.northwestern.edu/magazine/fall-2022/future-of-human-robot-interaction/
22. Space News - Latest Space and Astronomy News | Space, accessed August 8, 2025, https://www.space.com/news
23. Space Race Heats Up: Satellite Launch Blitz, Lunar Power Plays & Billion-Dollar Space Deals (Aug 5–6, 2025 Roundup), accessed August 8, 2025, https://ts2.tech/en/space-race-heats-up-satellite-launch-blitz-lunar-power-plays-billion-dollar-space-deals-aug-5-6-2025-roundup/
24. Space Race Heats Up: Satellite Launch Blitz, Bold Missions, and a ..., accessed August 8, 2025, https://ts2.tech/en/space-race-heats-up-satellite-launch-blitz-bold-missions-and-a-shuttles-surprise-move-aug-6-7-2025/
25. Astronauts launch to the space station after sidelined by Boeing's troubled Starliner, accessed August 8, 2025, https://apnews.com/article/spacex-nasa-astronauts-d90068c27fff2ed2438d1776e0632443
26. SpaceX delivers four astronauts to the International Space Station just 15 hours after launch, accessed August 8, 2025, https://apnews.com/article/nasa-spacex-astronauts-docking-64caca227f6ef4774de1fc14b05910bd
27. NASA aiming to build nuclear reactor on the moon by 2030 | Space, accessed August 8, 2025, https://www.space.com/astronomy/moon/nasa-aiming-to-build-nuclear-reactor-on-the-moon-by-2030
28. NASA plans to build nuclear reactor on the moon by 2030, outpacing

China-Russia lunar ambitions with a 100-kilowatt power system, accessed August 8, 2025, https://timesofindia.indiatimes.com/science/nasa-to-build-moon-reactor-by-2030-outpacing-china-russia-lunar-ambitions-with-a-100-kilowatt-power-system/articleshow/123118414.cms
29. NASA revises plans for commercial space station development - Copernical.com, accessed August 8, 2025, https://www.copernical.com/news-public/item/53011-2025-08-06-15-55-48
30. NASA Commercial LEO Space Stations Acquisition Strategy, accessed August 8, 2025, https://nasawatch.com/commercialization/nasa-commercial-leo-space-stations-acquisition-strategy/
31. Axiom Space, accessed August 8, 2025, https://www.axiomspace.com/missions/ax4
32. Where are America's Commercial Space Stations in 2025?, accessed August 8, 2025, https://www.spacescout.info/2025/06/where-are-americas-commercial-space-stations-in-2025/
33. NASA Plans To Build Nuclear Reactor On The Moon By 2030 I World News - YouTube, accessed August 8, 2025, https://www.youtube.com/watch?v=fDOahMrzZEw
34. NASA plans to put a nuclear reactor on the moon. Here's what that means, accessed August 8, 2025, https://www.ipm.org/2025-08-08/nasa-plans-to-put-a-nuclear-reactor-on-the-moon-heres-what-that-means
35. NASA Speeds Up Timeline For Nuclear Reactor On The Moon But ..., accessed August 8, 2025, https://www.iflscience.com/a-nasa-nuclear-reactor-on-the-moon-bold-proposal-is-unfeasible-by-2030-heres-why-80289
36. Sean Duffy accelerates plan for lunar nuclear reactor - Astronomy Magazine, accessed August 8, 2025, https://www.astronomy.com/science/sean-duffy-accelerates-plan-for-lunar-nuclear-reactor/
37. Can nuclear energy be produced on the moon? - Illinois News Bureau, accessed August 8, 2025, https://news.illinois.edu/can-nuclear-energy-be-produced-on-the-moon/
38. NASA's Moon Nuclear Reactor Plans Propel U.S. into New Space Race - AInvest, accessed August 8, 2025, https://www.ainvest.com/news/nasa-moon-nuclear-reactor-plans-propel-space-race-2508/
39. Nasa to put Nuclear Reactor on the Moon by 2030 - Reddit, accessed August 8, 2025, https://www.reddit.com/r/nasa/comments/1miaf42/nasa_to_put_nuclear_reactor_on_the_moon_by_2030/
40. What a nuclear reactor on the Moon really means for NASA's future - Big Think,

accessed August 8, 2025, https://bigthink.com/starts-with-a-bang/nuclear-reactor-moon-nasa/
41. 3D Printed Rocket Engine Market: Aerospace Additive Manufacturing Leaders 2025, accessed August 8, 2025, https://datahorizzonresearch.com/blog/3d-printed-rocket-engine-market-aerospace-additive-manufacturing-415
42. 3D Printed Space Rocket Market Predictions and Opportunities 2025-2033, accessed August 8, 2025, https://www.datainsightsmarket.com/reports/3d-printed-space-rocket-119083
43. Rocket Engines, 3D-Printed: The Future of Spaceflight - Nikon SLM Solutions, accessed August 8, 2025, https://nikon-slm-solutions.com/addictive-additive/rocket-engines-3d-printed-the-future-of-spaceflight/
44. Future Rocket Engines May Include Large-Scale 3D Printing - NASA, accessed August 8, 2025, https://www.nasa.gov/humans-in-space/future-rocket-engines-may-include-large-scale-3d-printing/
45. Marching towards Mars – ISS robot experiment 'Surface Avatar' successfully concludes, accessed August 8, 2025, https://www.dlr.de/en/latest/news/2025/marching-towards-mars-iss-robot-experiment-surface-avatar-successfully-concludes
46. UNIQUE CONSIDERATIONS FOR HUMAN-ROBOTIC INTERACTION IN HUMAN SPACEFLIGHT 1.1 Robots for Space - NASA Technical Reports Server (NTRS), accessed August 8, 2025, https://ntrs.nasa.gov/api/citations/20180000656/downloads/20180000656.pdf
47. Robots to help with human habitation in space, accessed August 8, 2025, https://seas.harvard.edu/news/2024/01/robots-help-human-habitation-space