Above and Beyond: A Holistic View of the Motivations for Human Spaceflight

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Introduction

Fifty years after humans first left footprints on extra-terrestrial regolith, missions by leading spacefaring states are now moving beyond planting flags. The goal has now become the establishment of a semi-permanent human presence through lunar bases and orbiting stations. In the long-term, actors such as the US, Europe, China, Russia, and India hope to use the Moon as a springboard for human travel to Mars, and beyond. The motivations of human spaceflight activities are remarkably diverse, and their analysis thus requires a holistic approach tackling why states support manned space missions as well as why individuals are willing to participate in them in spite of the extreme risks involved.

First, this essay discusses strategic geopolitical interests, which strongly encourage nations and regions to support human spaceflight activities as a means to ensure greater relevance in the international arena. Second, economic benefits related to manned missions are evinced, focusing upon the supporting of innovative technologies to be used in a multitude of industries, as well as the role of private sector entities and the relevance of human spaceflight to future activities such as in-situ space resource utilisation (ISRU). Third, motivations regarding scientific research and advancements are highlighted. Past instances of research conducted on and by humans on the International Space Station (ISS) are called upon to illustrate the benefits to scientific knowledge provided by manned missions to space. Finally, the essay argues that part of the motivations for human spaceflight arises from curiosity and a desire to explore, coupled with the human pursuit of a deeper understanding of our place within the universe.

Pursuit of Strategic Geopolitical Interests

At the dawn of the space age, human spaceflight was intrinsically tied to the race between the two superpowers, the United States and the Soviet Union, and their desire to prove their technological and societal superiority. Despite early Soviet successes, most prominently with the launch of Yuri Gagarin in April 1961, becoming the first human to orbit the Earth, Apollo 11's Moon landing sentenced the end of the space race: the US had won. More than 50 years later, the US, China, Russia, and Europe are experiencing a renewed determination to see their nationals and their flags not only visiting outer space, but establishing settlements on and around the Moon as a stepping stone to the conquering of Mars.

While international collaboration is certainly more common now than during the Apollo era, it is clear that the US (with Europe) and China (with Russia as junior partner) are the primary competitors in this new space race to the Moon and beyond, as argued by US Senator Jerry Moran.[1] The two space races share some limited commonalities in their foundational motivations: the proving of a state's technological and societal superiority, boosting national prestige, and ensuring a strategic victory over its competitors. However, this second-round of humans venturing towards

[1] Jerry Moran, "The Next Space Race", *SpaceNews,* March 23rd, 2021, last accessed March 30th, 2021, <https://spacenews.com/op-ed-the-next-space-race/>.

the Moon will not be limited to a flags-and-footprints approach, as settlements will be established in orbit and on the lunar surface.

Space diplomacy has been one of the most important aspects of US foreign policy, as it recognised its intrinsic potential to establish and maintain close cooperation with allied countries. Indeed, while national pride has played an undeniable role in the history of human spaceflight, a successful space programme "brings a certain level of diplomatic clout."[2] Successes in space endeavours carry an undeniable growth in a state's ability to exercise soft power, a concept popularised by Joseph Nye describing a country's capacity to "get other countries to *want* what it wants."[3] While this is to an extent true of all space activities, one can think of no greater avenue to captivate global attention than manned missions to celestial bodies.

The centrality of human spaceflight as a key component for the space policy of the US was on full display during the early weeks of the Biden administration. With the endorsement of Artemis by representatives of President Biden in February 2021, the programme became the "first major deep-space human exploration effort with funding to survive a change in

[2] Todd Harrison, "China in Space: A Strategic Competition", Statement before the US-China Economic and Security Review Commission, 116th Congress, 1st Session, April 25th, 2019, <https://www.uscc.gov/sites/default/files/2019-10/April%2025%202019%20Hearing%20Transcript.pdf>, p. 47.

[3] Joseph S. Nye, Jr., "Soft Power", *Foreign Policy*, No. 80, (1990): p. 166. (emphasis in original)

presidents since Apollo", after decades of programmatic alterations and cancellations punctuated by each new presidency.[4]

Further, in the press briefing delivered by White House Press Secretary Jen Psaki, wherein the administration's support to the programme was confirmed, it was remarked that the US would endeavour to send astronauts to the surface of the Moon to not only conduct scientific research, but also to "demonstrate America's values."[5] Psaki's statement is undoubtedly related to the fact that Artemis plans for a man and the first woman to walk on the lunar surface, in what would amount to a strong symbol in support of gender equality. However, it also suggests that a further reinforcement of America's long-held status of leading spacefaring nation is driving the effort to send humans into outer space, and that achieving such an age-defining technological feat will provide a marked bolstering to America's diplomatic and soft power.

The Artemis programme is far from the sole example of a human spaceflight effort geared in part towards the accumulation of a state's strategic diplomatic prowess. China, the US's primary competitor in space as well as in economic and military fields, has clearly recognised the value of an advanced civil space programme as a means to build consensus and

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[4] Christian Davenport, "The Biden Administration has Set Out to Dismantle Trump's Legacy, Except in One Area: Space", *The Washington Post,* March 2nd, 2021, last accessed March 21st, 2021, <https://www.washingtonpost.com/technology/2021/03/02/biden-space-artemis-moon-trump/>.

[5] Jen Psaki, in "Press Briefing by Press Secretary Jen Psaki and National Security Advisor Jake Sullivan", *White House – Briefing Room*, February 4th, 2021, last accessed Mach 21st, 2021, <https://www.whitehouse.gov/briefing-room/press-briefings/2021/02/04/press-briefing-by-press-secretary-jen-psaki-and-national-security-advisor-jake-sullivan-february-4-2021/>.

forge partnerships around the world. Notably, the Chinese have been barred from participation in the ISS, and have thus worked to develop their own orbiting crewed laboratory. Tiangong-1 and Tiangong-2 have in fact acted as precursors for the future Chinese large modular space station, planned to be approximately the size of the Russian Mir, or one-fifth of the mass of the ISS.

Chinese officials have already begun forging international cooperation agreements with several states, including established space actors. One such example is the 2017 agreement between the China Manned Space Agency and the Italian Space Agency on long-term human spaceflight activities.[6] In essence, the partnerships formed through its civil space programme may allow China to ensure greater cooperation on Earth leading to a more meaningful penetration of strategic markets and regions. More specifically, human spaceflight may play a key role in space diplomacy considerations, as China could "use the prospect of human spaceflight missions to its new space station, to the Moon, and one day to Mars as an incentive for other countries to partner with it in ways that further its terrestrial ambitions."[7]

Chinese space capabilities have soared in recent years, with recent missions carrying out lunar far-side landing and autonomous lunar sample

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[6] Redazione ASI, "Agreement Italy-China: The Italian Space Agency and the China Manned Space Agency cooperate on human spaceflight activities", *ASI – News*, February 22nd, 2017, last accessed March 22nd, 2021, <https://web.archive.org/web/20180216205351/https://www.asi.it/en/news/agreement-italy-china>.
[7] Harrison, *supra*, note 2, p. 42.

returns, demonstrating advanced expertise. The state has thus looked to capitalise on this momentum to further entrench its status as near-peer competitor to the US in space. One such avenue pursued by China has been to form a lunar base cooperation agreement with Russia, which shares ambitions for a permanent presence on the Moon but lags behind in technological development, thus joining as junior partner. Both states have clearly recognised the importance of space diplomacy as well as the economic potential of space on the future of the geopolitical balance of power.[8] They have thus acted in concert to counteract US attempts to lead an international effort to the Moon through its Artemis Accords by providing "an alternative to a US-led order in space."[9] Indeed, the Sino-Russian Moon base project was formally opened to international partners in late April 2021, in a consensus-building effort in reaction to the US-European plans.[10]

Clearly, strategic advantages to diplomatic strength provided by human spaceflight missions are not limited to the actors leading these efforts. Indeed, the pursuit of specific long-term strategic gains has informed Europe's strong support of human spaceflight. Europe, cooperating

[8] See Namrata Goswami in Steven Lee Myres, "China and Russia Agree to Explore the Moon Together", *The New York Times,* March 10th, 2021, last accessed March 21st, 2021, <https://www.nytimes.com/2021/03/10/world/asia/china-russia-moon.html>.
[9] Namrata Goswami, "The Strategic Implications of the China-Russia Lunar Base Cooperation Agreement", *The Diplomat*, March 19th, 2021, last accessed March 21st, 2021, <https://thediplomat.com/2021/03/the-strategic-implications-of-the-china-russia-lunar-base-cooperation-agreement/>.
[10] Andrew Jones, "China, Russia Open Moon Base Project to International Partners, Early Details Emerge", *SpaceNews*, April 26th, 2021, last accessed April 27th, 2021, <https://spacenews.com/china-russia-open-moon-base-project-to-international-partners-early-details-emerge/>.

through the European Space Agency, is an influential partner of the US in the Artemis programme, carrying out development of key systems such as the European Service Module (ESM) on the Orion spacecraft. Simultaneously, its efforts within the programme allow the region to work towards its primary goals of deepening integration throughout the continent, and supporting the advance of an autonomous, resilient, and competitive European space industry.

In essence, one of the motivations behind European investment into human spaceflight missions is the furthering of its technological and therefore strategic autonomy. World-leading capabilities in the manufacturing of life support systems have been developed through European participation to the ISS, with the development and operation of the Columbus module, as well as the ISS's Cupola, and Harmony and Tranquillity nodes. This expertise is clearly on display as Europe participates in the development of the Space Launch System (NASA's heavy launcher), the Lunar Gateway, and the aforementioned ESM on Orion, providing life support and power to the astronauts on their way on the Moon. Large System Integrators (LSIs) such as *Thales Alenia Space* and *Airbus Defence and Space* have gained extensive expertise through these projects, considerably benefitting European non-reliance on third parties in critical technologies. Human spaceflight missions such as those carried out on the ISS as well as long-term international efforts such as Artemis create fertile ground for cross-border technology transfer and knowledge sharing within the EU, deepening integration and spurring innovation both within and outside of the space sector. As Europe lacks the possibility to rely upon ultra-large privately-owned entities such as *SpaceX*, its quest to ensure strategic autonomy is necessarily linked to the support of both LSIs as well as small and medium-sized enterprises (SMEs), providing versatility and resilience to the European space industry.

A final consideration on the strategic geopolitical motivations of human spaceflight should be evinced; the pursuit of international collaboration. Manned missions are ideally suited for the furthering of close cooperation with states which are usually understood as competitors. While collaboration on robotic exploration frequently occurs, its resonance on the international community is muted compared to cooperation in human missions. When posed the question “why send humans to space?”, former ESA Director General Jan Wörner did not gloss over the importance of geopolitics, stating that “in the ISS we have Japanese, Canadians, Americans, Russians and Europeans […] This is really preaching earthly cooperation better than any robotic mission.”[11] Similarly, ESA Director of Human and Robotic Exploration David Parker highlighted the importance of collaboration in human spaceflight missions, stating that their nature

[11] Jan Wörner in Jonathan O’Callaghan, “Q&A: Human spaceflight is a risk worth taking, says ESA head”, *Horizon: The EU Research & Innovation Magazine*, April 10th, 2020, last accessed March 23rd, 2021, <https://horizon-magazine.eu/article/qa-human-spaceflight-risk-worth-taking-says-esa-head.html>.

allows for cooperation with any state, including earthly competitors, thus potentially alleviating tensions and favouring international diplomacy.[12]

Fostering Economic Development

The willingness to invest money and manpower to support the development of human spaceflight activities is neither limited to strategic geopolitical interests nor to state involvement. Economic considerations are deeply embedded in the motivations for manned missions to space. States have looked to spur economic development through both the creation of jobs and favouring research and development of innovative technologies, while private entities have long espoused the desire to send "tourists" into space, though this business venture has yet to become reality.[13]

Not only is the capitalisation of the huge economic potential of space writ large deeply related to the furthering of an entity's geopolitical might, but successful human spaceflight is a precondition to fully take advantage of the emerging cislunar economy.[14] Once again, the US and China are the two countries at the helm of international efforts, vying for the maximum exploitation of the economic potential of cislunar space, investing in

[12] David Parker in Jonathan O'Callaghan, "'The moon is a history museum and we've only visited the gift shop'", ", *Horizon: The EU Research & Innovation Magazine*, February 5th, 2019, last accessed March 23rd, 2021, <https://horizon-magazine.eu/article/moon-history-museum-and-we-ve-only-visited-gift-shop.html>.
[13] *Virgin Galactic, SpaceX*, and *Blue Origin* are perhaps the most notable companies working towards space tourism activities.
[14] The term cislunar is used to differentiate between the emerging possibilities on the lunar surface and the existing space economy in Low-Earth Orbit and Geosynchronous Equatorial Orbit.

human space exploration as foundational programmes for a swathe of operations. On the one hand, reliable estimates in terms of profitability of cislunar enterprises remain elusory; their sustainability is another source of speculation as governments remain the primary customers. On the other, the exploitation of space resources and related activities (propellant production, in-space manufacturing, in-space solar power generation to name a few) are much-touted due to the expected economic benefits to be reaped.

China offers a clear example. Officials have long recognised the path leading from human space exploration to economic development. China's exploration of the lunar south pole is thus not surprising, considering the abundance of ice found in permanently shadowed regions in craters on the lunar poles evidenced from remote sensing observations.[15] Human spaceflight is thus a means to establish a semi-permanent presence on the Moon, allowing for instance the exploitation of silicon dioxide for solar panel manufacturing, as well as the electrolysation of lunar water into oxygen and hydrogen to produce cryogenic propellant.[16]

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[15] See for instance Stewart Nozette et al., "The Clementine Mission to the Moon: Scientific Overview", *Science* 266, No. 5192, (1994): pp. 1835-1839, William C. Feldman et al., "Fluxes of Fast and Epithermal Neutrons from Lunar Prospector: Evidence for Water Ice at the Lunar Poles", *Science* 281, No. 5382, (1998): pp. 1496-1500, and Paul O. Hayne et al., "Evidence for Exposed Water Ice in the Moon's South Polar Regions from Lunar Reconnaissance Orbiter Ultraviolet Albedo and Temperature Measurements", *Icarus* 255, (2015): pp. 58-69.

[16] Xinhua, "Exploiting Earth-Moon Space: China's Ambition After Space Station", *China Daily*, March 8th, 2016, last accessed March 30th, 2021, <https://www.chinadaily.com.cn/china/2016-03/08/content_23775949.htm>.

The in-situ production of propellant has been recognised internationally as the most promising business activity in the short-term, with both governments and private actors such as the Japanse *ispace* investing in the research and development of relevant technologies. While part of the separated oxygen and hydrogen will necessarily be used for life support to astronauts on the Moon, the prospect of in-space refuelling has attracted the attention of all the leading spacefaring nations, due to the possibilities it creates. On the one hand, the cost of space activities is dominated by transportation costs, as fuel must be expended to climb out of Earth's gravitational well; the propellant requirements increase exponentially as farther destinations are targeted. On the other, refuelling in stations orbiting the Moon can result in a reduction in launcher size and a significant decrease in required fuel, serving to greatly reduce mission costs. As discussed by Sommariva et al, multiple refuelling may flatten out the curve describing the propellant mass in relation to the delta-v required for a space mission.[17]

[17] The delta-v budget of a mission is effectively an estimate of the total change in velocity required to carry out the mission in its entirety, and is dependent only on the specified orbital trajectory rather than mass of the vehicle or propulsion system type. Total delta-v required can be used to determine the amount of propellant needed for the mission given the vehicle's mass and propulsion. Andrea Sommariva et al., "The Economics of Moon Mining", *Acta Astronautica*, Vol. 170, (2020): pp. 713-714.

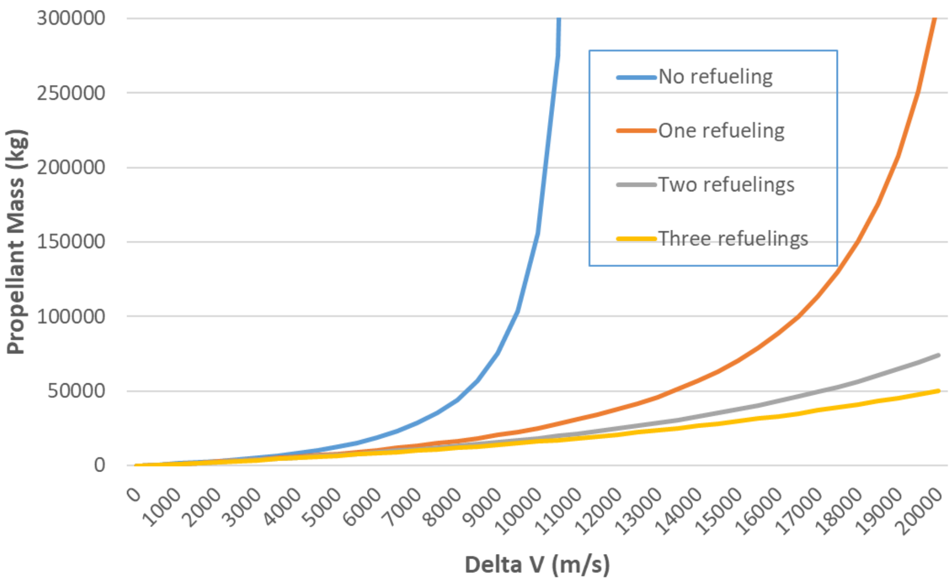

Figure 1 – Chart showing the significant reduction in propellant mass when multiple in-space refuelling are carried out taking advantage of the Moon's shallower gravitational well. *Credit*: Sommariva et al

Human exploration of Earth's neighbours and ISRU are thus in a symbiotic relation. While human missions to Mars and beyond will necessarily require a developed infrastructure enabling ISRU for life support and sustenance, the initial push for utilisation of lunar volatiles will be carried out as part of missions sending humans back to the Moon. In the long-term, a permanent lunar human settlement coupled with a developed resource extraction and utilisation infrastructure could provide age-defining economic and social benefits. Other than lunar water-ice, materials such as the coveted Helium-3, potentially allowing for safe and clean nuclear fusion energy production, as well as metals from near-Earth objects could be mined and transported back to Earth. Metals only rarely mined on Earth such as platinum, iridium, palladium, rhodium, and osmium are abundant on asteroids, whose economic value has thus been estimated at staggering amounts.[18] The technology required to sustainably and cost-effectively exploit extra-terrestrial materials is far from ready, though human exploration efforts will necessarily help spur research and development towards both ISRU and extraction of resources.

Moreover, human spaceflight activities also provide for more tangible (and less speculative) economic benefits for the states and regions investing in these long-term missions. Despite the difficulty in accurately portraying the direct and indirect benefits on a state's economy, different methodological approaches by numerous scholars have argued that financing space programmes provides a healthy return on investment (ROI).[19] While older, extreme estimates proposed an ROI of $7-8 for every $1 spent by the US for its Apollo programme and a staggering $40 for every dollar in the early 1990s, the potential for a substantial ROI from space investments is commonly recognised.[20] More realistic estimates commissioned by the UK Space Agency have suggested that ESA membership allows for an overall

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[18] For instance, 16 Psyche, one of the largest objects in the main asteroid belt, was valued at about $10,000 quadrillion. A NASA mission to investigate the asteroid was recently approved, with launch set for 2022. See Jamie Carter, "NASA On The Cusp With $967 Million Mission To Weird 'Psyche' Asteroid Worth 75,000 Times Our Global Economy", *Forbes*, February 3rd, 2021, last accessed April 1st, 2021, <https://www.forbes.com/sites/jamiecartereurope/2021/02/03/nasa-in-final-phase-with-psyche-1-billion-mission-to-an-asteroid-worth-70000-times-our-global-economy/?sh=31124d217898>.

[19] See for instance John Clarke et al., "Assessing the Full Effects of Public Investment in Space", *Space Policy*, Vol. 30, Issue 3A, (2014): pp. 121-134; Henry Hertzfeld, "Space as an Investment in Economic Growth", *AIAA Space Technology Conference & Exposition,* September 1999, AIAA-99-4548; and William Ricard et al., "A New Perspective on Innovation in Space and Its Implications on the Tools and Measures Used to Assess the Indirect Impacts of Public Investment in the Space Sector", *New Space*, Vol. 3, No. 2, (2015): pp. 87-91.

[20] Kathleen J. Murphy, "Sourcing and Sustaining Optimum Financing", in Mary Fae McKay, David S. McKay, and Michael B. Duke (eds.), *Space Resources Social Concerns,* NASA SP-509, Vol. 4, (Washington, DC: U.S. Government Printing Office, 1992): p. 103.

direct-only rate of return of £3-4 for every £1 invested by the UK, to which one must add indirect, spill-over returns common to all R&D investments, valued at about £6-12 per £1.[21]

The economic benefits arising directly from space activities as well as being enabled by technology transfer of innovative solutions to non-space industries is common to all space investments. Nevertheless, human exploration missions have played and continue to play a key role in catalysing both public and private investments in the space industry, creating fertile ground for thousands of jobs and development of ground-breaking technologies. The economic significance of human spaceflight was on full display during the Apollo era, when up to 400,000 people worked in support of the US's goal of landing humans on the Moon and returning them safely to Earth.

George H. W. Bush, in his remarks at the 20th anniversary of the Moon landing, highlighted the dividends paid by the Apollo programme, quoting news outlets stating that Apollo had been "the best return on investment since Leonardo da Vinci bought himself a sketch pad." [22] Hyperboles aside, the economic relevance of human spaceflight missions was as clear for President Bush in 1989 as it is today. Similarly, the crucial steps and core

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[21] Greg Sadlier et al., "Return from Public Space Investments An Initial Analysis of Evidence on the Returns from Public Space Investments", *London Economics,* October 2015, available at <https://londoneconomics.co.uk/wp-content/uploads/2015/11/LE-UKSA-Return-from-Public-Space-Investments-FINAL-PUBLIC.pdf>, pp. 58-59.

[22] George H. W. Bush, "Remarks on the 20th Anniversary of the Apollo 11 Moon Landing", July 20th, 1989, *The American Presidency Project,* <https://www.presidency.ucsb.edu/documents/remarks-the-20th-anniversary-the-apollo-11-moon-landing>.

strategies to be followed to ensure successful human exploration have not changed either. Indeed, President Bush set out a roadmap including the creation of Space Station Freedom (which later evolved into the ISS), then "back to the Moon; back to the future. And this time, back to stay", and finally "a journey into tomorrow: a manned mission to Mars."[23]

While political and budgetary support for human exploration efforts have stagnated in past decades, the Artemis programme, with the support of Europe, and the Sino-Russian efforts at lunar exploration arise from similar views and aspirations as those expressed by President Bush in 1989. Indeed, the Artemis programme is understood as a means through which to reassert the US's "status as the world's leading spacefaring nation", all the while ensuring benefits "well into the future, not just for the space programme but for American society writ large."[24] These will certainly not be limited to any one party or state, as public and private actors in non-space industries operating throughout the world will benefit from research and development of innovative technologies carried out as part of Artemis.

Past and current examples of spinoff technologies initially created for human spaceflight abound. Sensors working to detect damages caused to launchers are used in bridges, while sustainable life-support systems for water recycling, waste management, or solar energy production greatly

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[23] *Ibid.*

[24] Peter Juul, "Taking Advantage of a Pivotal Decade in Outer Space", *Center for American Progress*, October 28th, 2020, last accessed April 6th, 2021, <https://www.americanprogress.org/issues/security/reports/2020/10/28/492236/taking-advantage-pivotal-decade-outer-space/>.

advance efforts on Earth pushing for a green economy.[25] Most relevant to current efforts tackling the COVID-19 global pandemic, the highly-insulating and extremely lightweight aerogels used on the ISS have been identified as suitable for ensuring reliable and sustainable cryogenic storage, and have thus been used for vaccine transportation.[26]

Supporting Scientific Research

Together with geopolitics and economics, motivations spurring the renewed interest for human spaceflight include the furthering of scientific research. While robotic missions have allowed access to a wealth of new information and knowledge about deep space, the Solar System, and Earth itself through remote sensing, human missions to space stations and the Moon offer unique avenues to explore. Human spaceflight has in the past aided the advancement of science in different fields; current efforts to send women and men to the Moon will likely produce similar, wide-ranging results. In particular, life sciences have benefitted greatly from a human

[25] John Olson et al., "Voyages: Charting the Course for Sustainable Human Space Exploration", *NASA*, 2011, available at <https://www.nasa.gov/sites/default/files/files/ExplorationReport_508_6-4-12.pdf>, p. 5.

[26] "Simple and Reliable Cold Chain Solutions for the Distribution of COVID-19 Vaccines", *AeroSafe Global,* 2021, last accessed April 6th, 2021, <https://cdn.ymaws.com/www.immunizationmanagers.org/resource/collection/E5F4FF65-9858-48AF-9B61-8DEAE2D881ED/AeroSafe_COVID-19_Shipping_Solutions_Presentation_-_Jan_2021_v2.pdf>. Aerogels are often referred to as the world's lightest solid materials, making them ideally suited for space travel. See Tori Woods, "Aerogels: Thinner, Lighter, Stronger", *NASA – Aeronautics*, July 28th, 2011, last accessed April 6th, 2021, <https://www.nasa.gov/topics/technology/features/aerogels.html>. For more information see "Open Source Aerogel", *Aerogel.org,* 2021, last accessed April 6th, 2021, <http://www.aerogel.org/>.

presence in space, though fields such as climate action also stand to gain valuable knowledge through human spaceflight activities.[27]

Health on Earth has been greatly benefitted from research conducted aboard the ISS. On the one hand, studies have focused upon how human bodies (as well as other animals and plants) react to microgravity and the environment within the space station. These have looked to improve our knowledge of life support systems for atmosphere management as well as methods to keep astronauts as healthy as possible for longer stays in outer space through exercise, thus overcoming muscle atrophy and bone decay. On the other hand, astronauts are far from the only people benefitting from research in space. For instance, great advancements in vaccine development for pathogens such as Salmonella and Streptococcus were favoured by work carried out aboard the ISS.[28]

Further, research on the immune system of astronauts and the behaviour of microbes in microgravity has fostered understanding of immune functions and the "developing of improved therapeutics to battle infectious diseases on Earth."[29] The work carried out on the ISS National

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[27] Mark Shelhamer, "Why Send Humans into Space? Science and Non-Science Motivations for Human Spaceflight", *Space Policy*, Vol. 42, (2017): pp. 37-40.

[28] Tara Ruttley, "International Space Station Plays Role in Vaccine Development", *ESA – Science & Exploration*, 2012, last accessed April 8th, 2021, <https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/International_Space_Station_Benefits_for_Humanity/International_Space_Station_Plays_Role_in_Vaccine_Development>.

[29] Rachel Clemens, "Infection Disease Research on the ISS National Lab", *ISS National Laboratory – Center for the Advancement of Science in Space*, March 26th, 2020, last accessed April 8th, 2021, <https://www.issnationallab.org/iss360/infectious-disease-research-perspectives-wvic/>. See also John Creech, "Innovation on the ISS to Improve Medicines on Earth", *ISS National Laboratory – Center for the Advancement of Science in Space*, October 24th, 2017, last accessed April 8th, 2021,

Laboratory will continue to deepen our knowledge and shed light on new possibilities in immunotherapy and vaccine research and development. Global pharmaceutical companies such as *AstraZeneca* and *Sanofi Pasteur* have recognised the huge potential of space for health research, looking to use results from experiments on the ISS to "improve the rate at which immunotherapies can be manufactured here on Earth" as well as "better methods of vaccine production and improve vaccine efficacy."[30]

Studies pertinent to human health on Earth as well as in space have been a mainstay of ISS missions. VITA (Vitality, Innovation, Technology, Ability) is one example; as part of the large swathe of experiments carried out by the ISS crew were several focused upon biological and physiological sciences.[31] While many experiments that have been flown to the ISS have been heavily automatized in order to minimise crew involvement, human spaceflight has had a marked influence on the possibilities for further research into disease prevention and cure on Earth.[32] As argued by Shelhamer et al, "findings from spaceflight research have provided a foundation for enhancing healthcare terrestrially and have increased our knowledge of

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<https://www.issnationallab.org/iss360/innovation-on-the-iss-to-improve-medicines-on-earth>.

[30] Ruttley, *supra*, note 28.

[31] Alessio Chiodi, "Terapie 'extraterrestri', anche l'Italia sperimenta tra stelle e pianeti", *AboutPharma*, July 25th, 2018, last accessed April 8th, 2021, <https://www.aboutpharma.com/blog/2018/07/25/terapie-extraterrestri-anche-litalia-sperimenta-tra-stelle-e-pianeti/>. For more detailed information on the VITA mission, see "Vita Mission", *ESA*, 2018, last accessed April 8th, 2021, <https://blogs.esa.int/VITAmission/>.

[32] See for instance Amelia Williamson Smith, "Examining Nanoparticle Formation in Microgravity for Improved Therapeutic Cancer Vaccines", *ISS National Laboratory – Center for the Advancement of Science in Space*, June 5th, 2019, last accessed April 8th, 2021, <https://www.issnationallab.org/iss360/examining-nanoparticle-formation-in-microgravity-for-improved-therapeutic-cancer-vaccines/>.

basic physiological processes" in diverse fields such as bone physiology, cardiovascular and pulmonary systems, and neurovestibular studies.[33] The continued support of the ISS partners to extend the station's life, as well as the Chinese plans to launch their own orbiting space station, will undoubtedly ensure further progress in these and other related fields.

Moreover, human spaceflight missions provide fertile ground for the research and development of technologies in several other scientific areas. Amongst the strongest argument in favour of a scientific rationale for human spaceflight was proposed by I.A. Crawford, who posited that support to human space programmes allow for facilities and capabilities "which purely scientific budgets could never afford to develop, but which nevertheless act to *facilitate* scientific research which would not otherwise take place."[34] In essence, future missions to the Moon, Mars, and beyond will at least allow for the "acquisition of scientific data which would not be obtained otherwise", and perhaps open new avenues tackling fundamental challenges to Earth's environment such as energy production and recycling of water and waste.[35]

An advanced and sustainable human spaceflight infrastructure may well serve as the basis for on-orbit and in-space manufacturing, in turn enabling the eventual development of Space Solar Power Satellites (SSPS) for massive energy production. While these efforts were briefly investigated

[33] Mark Shelhamer et al., "Selected Discoveries from Human Research in Space that are Relevant to Human Health on Earth", *npj Microgravity,* Vol. 6, No. 5, (2020).
[34] I.A. Crawford, "The Scientific Case for a Human Spaceflight Infrastructure", *Earth, Moon, and Planets,* Vol. 87, (1999): p. 221. (Emphasis in original)
[35] *Ibid.*

and ultimately abandoned by NASA decades ago, China has established a long-term incremental roadmap leading to the construction of large space solar power stations by 2035.[36] As noted by several observers as early as the 1970s, the reduced launching costs from the Moon due to its shallower gravitational well and absence of atmospheric drag could render the creation of space solar power stations more economically viable.[37]

This scenario necessarily entails a highly advanced infrastructure for ISRU on the lunar surface, which is itself a core aspect of human spaceflight missions proposed by states as well as those envisioned by private companies such as *SpaceX* and *Blue Origin*. As noted by Davis, the "moon first" approach taken by both public and private actors "opens up the possibility of an SSPS race centred on ensuring access to the lunar 'high ground' to get the vital resources required for building large structures."[38] Needless to say, the actualisation of these plans and the successful creation of energy production facilities in outer space could have epochal consequences on life on Earth, potentially rendering coal and other fossil fuels quasi-obsolete.

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[36] See for instance Namrata Goswami, "China in Space: Ambitions and Possible Conflict", *Strategic Studies Quarterly,* Vol. 12, No. 1, (2018): pp. 74-97, and "China to Build Space-Based Solar Power Station by 2035", *XinhuaNet*, December 2nd, 2019, last accessed April 9th, 2021, <http://www.xinhuanet.com/english/2019-12/02/c_138599015.htm>.

[37] O'Neill was amongst the first to predict these long-term efforts. See Gerard K. O'Neill, *The High Frontier: Human Colonies in Space*, (New York City: William Morrow and Company, 1977): pp. 56-59.

[38] Malcom Davis, "Space-based Solar Power and 21st-Century Geopolitical Competition", *Australian Strategic Policy Institute*, April 2nd, 2019, last accessed April 9th, 2021, <https://www.aspistrategist.org.au/space-based-solar-power-and-21st-century-geopolitical-competition/>.

While these are decidedly long-term objectives, scientific research can be advanced by humans in space in the short-term as well. With the definition of the scientific goals of Artemis III, NASA has established detailed plans on what investigations the crewmembers who will land on the Moon will perform. Specifically, the priorities are increasing knowledge of the formation and evolution of the Moon, its interaction with the Sun, and how water and other resources arrived and are preserved on the Moon.[39] In more general terms, human spaceflight missions have an unmatched capacity to push the boundaries of space science as well as scientific research benefitting industries and individuals on Earth.

Chasing Curiosity Towards Discovery

Forcing some recession of the boundaries of our existence has spurred humans into action for centuries, braving unknown oceans, sand and ice deserts, mountains, and space, the ultimate frontier. When the famous English mountaineer George Mallory, notorious for his multiple attempts at conquering Mount Everest, was asked why he chose to climb the tallest mountain on Earth, he reportedly uttered the three most famous words in mountaineering: "because it's there." While the quote itself is likely apocryphal, the sentiment it embodies is a clear illustration of the human drive to continuously push the boundaries of nature. Astronauts, acting as "envoys of mankind" as defined in Article V of the Outer Space Treaty of

[39] Artemis III Science Definition Team Report, *NASA*, NASA/SP-20205009602, December 2020, available at <https://www.nasa.gov/sites/default/files/atoms/files/artemis-iii-science-definition-report-12042020c.pdf>.

1967, endanger their lives by spearheading a collective effort to overcome the perceived limitations of our environment.

Further, human spaceflight and space exploration provide unequalled opportunities "to engage and inspire the next generation of explorers – in the hopes that they will embrace and continue the journey of discovery."[40] On the one hand, communicating the excitement of space exploration and the rewards of chasing curiosity towards discovery may encourage students to pursue careers in science, mathematics, and engineering. On the other, witnessing epochal breakthroughs inspires individuals and groups to recognise their own capabilities in overcoming the preconceived boundaries they may encounter in their endeavours. Our cultural collective fascination of space as the final frontier of discovery and wonder makes this process all the more impactful.

To consciously take on the extreme challenges of space travel and not only be guided by but actively foster human curiosity partly informed the Apollo missions, especially considering the US's communication strategy with its population. President Kennedy's address at Rice University, amongst the most famous speeches of the 20th century, undeniably focused on humans' will to take on what previous generations may have understood as impossible tasks, in defiance of risks and hardships:

[40] John Olson et al., *supra*, note 25, p. 5.

> But why, some say, the Moon? Why choose this as our goal? And they may well ask, why climb the highest mountain? Why, 35 years ago, fly the Atlantic? Why does Rice play Texas?
>
> We choose to go to the Moon. We choose to go to the Moon... We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard; because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win, and the others, too.[41]

With these words Kennedy helped secure the support of the American population for the space effort, in spite of those members of Congress who "would have us stay where we are a little longer to rest, to wait."[42] Similar sentiments are informing today's second wave of space travel to the Moon and beyond; the characterisation of space as an ultimate frontier as well as the encouraging of humans' pioneering spirit are clear commonalities between then and now.[43]

Finally, humankind has been driven by the prospect of new knowledge. As discussed above, manned spaceflight will foster scientific research of numerous fields, benefitting industries, individuals, and the environment on Earth. However, human spaceflight may offer opportunities to garner a more profound knowledge, allowing for better understanding of the

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[41] John F. Kennedy, Address at Rice University on the Nation's Space Effort, September 12th, 1962, available at <https://er.jsc.nasa.gov/seh/ricetalk.htm>.
[42] *Ibid.*
[43] John W. Jordan, "Kennedy's Romantic Moon and its Rhetorical Legacy for Space Exploration", *Rhetoric and Public Affairs*, Vol. 6, No. 2, (2003): pp. 209-232.

environment which surrounds our planet. Ultimately, to know the universe is to know our place within it, and the overcoming of physical boundaries for humanity may lead to rediscovering lessons concerning our own existence on Earth. In spite of extensive theoretical knowledge and data from robotic missions, a concrete human experience has an unparalleled capacity in causing a shift in perspective, simultaneously assuaging and fostering our need for discovery. Perhaps the best example is provided by the Apollo missions, during which humankind did not only become privy to the constitution of the Moon, but was also shown the beauty and fragility of Earth as viewed from far above its atmosphere.

Amongst the most iconic image taken as part of the Apollo programme is known as *Earthrise*, taken during Apollo 8. This image of Earth rising from the lunar horizon stands as testament to the opportunities for boundless discoveries through the human exploration of space and celestial bodies. An oft-quoted tenet attributed to Socrates would have that “man must rise above Earth to the top of the atmosphere and beyond, for only then will he fully understand the world in which he lives.”[44] Human exploration of celestial bodies and the space between them will thus serve as an “expansion of the realm of human experience – bringing people into new

[44] Although the quote itself is likely apocryphal, similar ideas are spoken by Socrates in Plato’s *Dialogues*. See Plato, *Plato in Twelve Volumes*, Vol. 1 translated by Harold North Fowler, (Cambridge: Harvard University Press, 1966): Phæto 109.

places, situations, and environments", and ultimately helping to redefine what it means to be human.[45]

Figure 2 – Earthrise, taken by William Anders (Apollo 8) after the crew's fourth orbit around the Moon, immortalised the first time humans witnessed in person the rising of Earth from the lunar horizon. *Credit:* NASA

[45] David A. Mindell et al., "Why Fly People into Space? The Future of Human Spaceflight: Objectives and Policy Implications in a Global Context", *American Academy of Arts & Sciences*, 2009, last accessed April 20th, 2021, <https://www.amacad.org/publication/future-human-spaceflight-objectives-and-policy-implications-global-context>.

Conclusion

Space has fascinated humans for millennia, and space travel has been imagined and written about for just as long. In recent history, one can recall literary descriptions of human spaceflight by Cyrano de Bergerac, R.E. Raspe, Jules Verne, and H. G. Wells among others. Arthur C. Clarke's 1951 short story *The Sentinel* was adapted in 1968 into one of the most pioneering and acclaimed movies in cinema history, *2001*: *A Space Odyssey*. *Project Moonbase* sought to realistically portray not only men *and* women in space, but orbiting the Moon and surveying potential sites for lunar bases as early as 1953. It is thus no surprise that Yuri Gagarin's historic flight, together with the Moon landing of Apollo 11, have entered the global social imaginary to an unprecedented extent, inspiring not only the 600 million people who watched the live feed from Tranquillity Base, but following generations as well.

A second wave of human spaceflight is now defining the space policy of leading spacefaring states. Although chances of profound international collaboration do exist, the world will likely experience a second space race. However, while during the first bout for spatial supremacy US astronauts spent a maximum of 22 hours exploring the lunar surface (Apollo 17), the modern race will be won with the establishment of orbiting stations and lunar bases. In essence, human spaceflight activities seek to colonise the Moon establishing a semi-permanent presence, with a view to expand humanity's reach to Mars and beyond. In conclusion, motivations for human spaceflight activities are as complex as the technologies which enable them: strategic geopolitical interests, economic benefits, supporting scientific research and advancements, and a response to an inner human desire to explore and understand the unknown are all relevant and interdependent explanations as to why both states and individuals want to travel to space.

Just as Armstrong recognised humankind's giant leap in 1969, the renewed efforts for manned missions to the Moon and Mars may herald a few more. Human spaceflight is in the long-term uniquely equipped to foster international collaboration, as no state will want to risk disastrous conflicts in outer space once settlements are established. Further, with NASA's Artemis missions the world will witness the first woman walking on the Moon as not only a symbol of gender equality but hopefully as an inspiration for all women to pursue their dreams and aspirations. Finally, research into water, waste, and resource management as well as energy production in space may have far-reaching consequences on Earth's battle against climate change, perhaps aiding humanity's transition to a greener existence.