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JOURNAL of SPACE PHILOSOPHY

Tenth Anniversary Edition: Building on the Past, Charting the Future

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Journal of Space Philosophy

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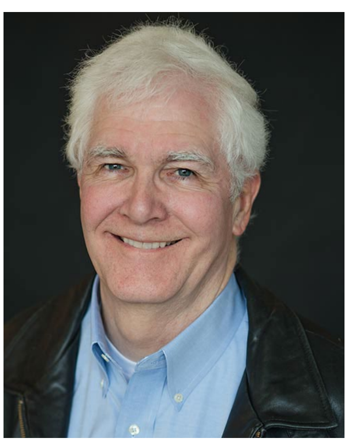
Frank White



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Frank and his wife Donna live outside Boston, MA.

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Steven Wolfe is Beyond Earth Institute President and Co-Founder. He is also the Global Spaceport Alliance's Deputy Executive Director and a CWSP International partner. He is on the Board of the Global Entrepreneurship Network—Space and the Board of Editors for the *Journal of Space Philosophy*. Steve served in Washington as the executive director of the Congressional Space Caucus and drafted the Space Settlement Act of 1988. The bill was signed into law as part of the NASA Authorization bill. Steve is the author of *The Obligation: A Journey to Discover Human Purpose on Earth and in the Cosmos*.

Dedication

This issue is dedicated to all the philosophers who have contributed to this journal over the past decade, and to all those whose thoughts and visions will fill its pages in the decades to come.

Their work helps us all to be clear headed and grateful as we face the challenges and opportunities ahead.

Gordon Arthur, Editor-in-Chief
Mark Wagner, Associate Editor

Preface

Gordon Arthur and Mark Wagner

This issue marks the tenth anniversary of the *Journal of Space Philosophy*. As such, it focuses on both retrospective and prospective articles, while still including other material. The first article, by Gordon Arthur, focuses on the development of the journal and what was happening behind the scenes. Then, Frank White looks at the development of space philosophy over the last decade. Madhu Thangavelu looks at the spiritual imperative for human space activity, and Grace Jones offers a short history of faith in the American space age.

Moving to the prospective articles, John Mankins offers a view of the evolving markets for space-based solar power, Rebecca Schembri traces the rise of the Chinese space program, Mark Wagner et al. explore K12 education in space, Izzy House examines marketing in space, and Priyanka Das Rajkakati discusses art in space.

Finally, Michael Goff discusses the urgency of space migration and Nick Nielsen asks whether space philosophy can even be considered a distinct subject.

We are grateful to all our contributors to date for their work, and we look forward to continuing to publish new articles in the years ahead. We always welcome papers from existing and new contributors. Please send articles for consideration to Mark Wagner at markdwagner@gmail.com.

Journal of Space Philosophy

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Access to the Journal of Space Philosophy and free downloading of its articles is available at www.keplerspaceinstitute.com/jsp. Contributors may submit articles or letters to the editor to markdwagner@gmail.com.

The First Ten Years of JSP: A Retrospective

By Gordon Arthur

Abstract
This article gives an overview of the first ten years of the *Journal of Space Philosophy* along with some of the backstory of its formation that has not previously been documented. It summarises some of its achievements so far, and it concludes with a brief look to the future.

Keywords: Space philosophy, history, first ten years, looking to the future.

Introduction

In 2012, the late Bob Krone saw a need for a journal on space philosophy. Since he could not find one, he decided to create one. He therefore assembled an editorial panel of experts on space and commissioned twenty articles for the inaugural issue. As I am qualified in philosophy and I have the necessary publication skills, he invited me to become Associate Editor while he took the Editor-in-Chief role, and this led to a productive collaboration that lasted until his death in late 2021. Shortly before his death, we both independently realised that Mark Wagner would be an excellent successor for him. I became Editor-in-Chief, retaining my publication duties, and Mark took over commissioning articles as Associate Editor.

Starting Out

Our initial intention was to set up an online-only journal that would work as well in print as on the screen and in which the authors would retain copyright on their articles. This resulted in the first issue being in a hybrid, compromise format that was not entirely successful. We also used broadly generic Kepler-branded covers at first, subsequently replacing them after we introduced graphic covers in Volume 4 in Spring 2015. However, as always with journals, the most important element was the content. The lead article in the first issue was by Joel Isaacson on recursive distinctioning, a subject that was dear to Bob's heart and to which the journal returned on several occasions. In addition, Bob set the tone for the journal going forward in his article "Philosophy for Space: Learning from the Past—Visions for the Future," in which he addressed the questions, what should be the philosophical foundation for the future of humans in Space? What beliefs and values will drive human Space settlements? What is the future for humankind if it remains on Cradle Earth? These questions led him to propose that Kepler's philosophy should be to encourage reverence for life within ethical civilization using the policy sciences as tools. Frank White began a three-part series on the Overview Effect, and the subjects of other articles ranged from the art of staying human and circumventing Armageddon to the philosophy of kids in space and the benefits of renewable energy.

By the second issue, the layout and formatting had improved somewhat, and the referencing standard had been set as Chicago (at that point, v16). Volume 2 explored dark energy, space law, and faith in space. It ventured into fiction with a journey into the unknown. It explored ways to unlock universal truths from philosophers' dreams, in parallel with applying them to developments in space science. It also introduced another mainstay, space settlement, to which it has returned on several occasions. Volume 3 built upon these ideas, and it also introduced space-based solar power, another main theme, concerning which Mike Snead compared the Earth to the Titanic sailing into an ice field, demonstrating that America's continuing reliance on fossil fuels is likely to lead to economic and cultural disaster. It also introduced material on leadership, with Yehezkel Dror stating that concern for the good of all humanity holds the key to the advancement of civilization into space. By this time, the journal had largely reached a stable format. The final element was graphic covers, which were introduced in the Spring 2015 issue. The journal retained this layout until it was revised to its current format in January 2021.

Becoming Established

Volumes 4–10 built on the foundation of earlier issues. Steven Wolfe expounded on our obligation to expand life beyond Earth, and David Norris and Frank White transferred the lessons from the Overview Effect to leadership in a terrestrial context, emphasising the importance of action and creativity. Yehezkel Dror wrote about preventing hell on Earth. Paul Werbos and Edward McCullough argued that America's space program should be resurrected by focusing on new technology. I wrote a reflection on crossing a border to see the solar eclipse of August 21, 2017 in Oregon, an eclipse that led to a brief revival in public interest in astronomy (the next major eclipse in North America is on April 8, 2024). Kim Peart and Madhu Thangavelu reflected on peace and the spiritual dimensions of space, and Ayse Oren wrote on space architecture. David Schrunk and Bob Krone wrote on the science of laws. Richelle Gribble wrote on art in space. Barry Elsey and Amina Amarova wrote on education in space (a subject on which Mark Wagner and others subsequently contributed). Larry Downing wrote on ethics, values, and moral leadership in space settlements. Bob Krone wrote on machine intelligence, and I wrote on the beginnings of the academic philosophy of space travel. There were special issues on recursive distinctioning and Yehezkel Dror's legacy.

Due to production problems and other commitments, we missed two issues, and there were also a few delayed issues. However, we felt it important to persevere through these problems and to keep publishing material. This is just a sample of the contents of these volumes. Our aim was and is to publish on all philosophical aspects of space exploration, and our authors have all made valuable contributions to that effort, covering a wide range of subjects and perspectives in the process. We have also made a point of inviting new writers as well as established authors, so that we can see new perspectives and viewpoints, and this intention remains. However, nothing lasts forever, and in mid-2021, we learned that change was in the air.

Changing of the Guard

In summer 2021, it became clear that Bob was not well, and that he would have to step back. Accordingly, he suggested that we swap titles so that I became Editor-in-Chief, and he became Associate Editor. It was not long after that that he realised he would have to retire altogether and suggested Mark as his successor. I had seen where things were going, and I had already concluded that Mark was right for the job. Accordingly, Mark and I took over during the preparation of the Fall 2021 issue. This was a special issue in memory of Joel Isaacson, who had died earlier in the year, and it focused heavily on recursive distinctioning. It was also a transitional issue, as we worked out how we would do things going forward. Spring 2022 was our first complete issue together. We decided that we would continue to follow the path set in 2012, and that the inevitable changes would be incremental and evolutionary, rather than revolutionary.

Trends

In the first issue, there was a broad range articles on a variety of different subjects. While we have attempted to continue that diversity of both articles and authors in subsequent issues, a few definite trends have emerged. Early on, there were foci on recursive distinctioning and its consequences, and the policy sciences. As time went on, however, streams of articles on space settlement, its prerequisites, and its consequences, along with space-based solar power and resource mining in space also emerged, and the focus slowly shifted from an initially fairly theoretical approach to a more practical and applied one. There is always a place for both theory and practice, however, so our aim is to seek a balance of both going forward.

Conclusion

So what of the future? Our intention is to build on this legacy and to continue to develop and refine our processes and our thinking, while adjusting the presentation as necessary from time to time. We remain open to good, new material from both established and new writers. We celebrate our contributors so far, and we remember their contributions with gratitude. In short, we look forward to continuing and developing what has gone before as we move into the future.

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About the Author: Gordon Arthur is Editor-in-Chief of the *Journal of Space Philosophy* and Dean of Space Philosophy and Theory at Kepler Space Institute. He has taught courses in both philosophy and governance at Kepler. He has published books in theology and journal articles in both philosophy and theology.

Editor's Notes: This issue is both a retrospective of the past ten years in space philosophy, and a prospective look at the next ten years. We begin with several articles highlighting the changes we've seen in the field since this journal began in 2012. Dr. Gordon Arthur, who served as the associate editor of the journal from its inception until 2021, and who now serves as the editor-in-chief since the passing of Dr. Bob Krone, offers his unique perspective on the founding and evolution of the journal. We are grateful that he has captured these stories and shared them here for posterity. ***Mark Wagner.***

Space Philosophy: A Ten-Year Retrospective

By Frank White

Is it really possible that it was ten years ago that the *Journal of Space Philosophy* published its first edition, and it included my essay, "Deep Space: The Philosophy of the Overview Effect?" Since that time, space philosophy has made great strides, and it seems more like a century than a decade.

One of the most significant developments has simply been the growth of interest in space philosophy itself. Back in 1986, when I decided to dub myself a space philosopher, it was not because I had been trained as a philosopher—far from it. Rather, I saw a need for a new space philosophy and did not see anyone taking up the challenge. In that way, I became a space philosopher by reinventing myself and working at the task of creating this different way of thinking. I was not interested in an abstract approach to the topic, using words like *epistemology* and *ontology* that are not easy to understand or apply. Rather, I was attracted to another meaning of the word *philosophy*, which refers to basic ideas about how to do something or how to live one's life. As one of the editors of *JSP,* Gordon Arthur notes:

> The Greek word *philosophia*, the root of the English word philosophy, means love of wisdom. This can as easily be practical wisdom as theoretical wisdom. Aristotle's main preoccupation was seeking virtue, not abstract knowledge: for the ancients, philosophy was about how to live as much as how to think.

I agree with Arthur, and with Aristotle!

Fast-forward twenty-six years to 2012, and the first edition of the *JSP*. That publication represented a milestone in itself, and suddenly, I no longer felt alone. Instead, I was sharing my ideas in a journal dedicated to the topic I had been attempting to highlight for more than two decades. My contribution to that first edition built on the foundation of Overview Effect theory, of course, but it suggested that we needed to go beyond that initial framework as we looked outward into the solar ecosystem. My essay argued that we needed the new philosophy of space exploration to go beyond asking how this great adventure might benefit humanity and asking how it might benefit the universe (which I later dubbed *Cosma*). Today, that case has been made in the third book of the Overview Trilogy, *The Cosma Hypothesis: Implications of the Overview Effect.* (I am deeply grateful to Dylan Taylor for publishing *Cosma,* and for ultimately becoming the publisher, through his Multiverse Media, of almost all of my books.)

The Cosma Hypothesis suggests that humanity has evolved to the brink of becoming a spacefaring species because as we explore the universe, we bring life, intelligence, and self-awareness to the cosmos. Thus, our benefit to Cosma is that we assist her to become increasingly more alive, intelligent, and self-aware. This great purpose forms the essence of a new philosophy of space exploration. It embraces exploration over exploitation, though both are needed if humanity is going to expand beyond the planet of our birth. It seeks a balance between these two inclinations, with the basic principle that we give as much to Cosma as we take from her.

Moreover, *The Overview Effect* included a big idea that garnered little attention for quite a while—the Human Space Program. As I finished writing the first edition of the book, it became clear from what the astronauts had told me that exploring the universe was much too big a task for one space program, one country, or one company. It should be a global commitment, a central project for all humanity. I proposed such a program and waited for someone to implement it, but for decades no one did! Eventually, my colleagues and I established the Human Space Program, Inc. (HSP) as a nonprofit 501 (c) 3 organization, which is now functioning with an energetic team of volunteers and support from a wide range of people. It is slated to be a millennium-long project, which technically began in 2000 (the date specified in *The Overview Effect*), so we are only 22 years into it! There is a long way to go!

HSP's efforts are also centered around the Overview Effect, and in that sense, the organization embodies the new philosophy. In addition, the initial foundation document is included in *The Cosma Hypothesis,* so it is available for all to see, and is associated with that particular effort to create a new space philosophy. In addition, HSP has given birth to another significant project almost by accident, one that fosters the development of the new space philosophy on a weekly basis. This is the Overview Round Table, which meets online every Wednesday at noon ET. I founded the Round Table, with the support of my HSP colleagues, to respond to the onset of the COVID pandemic in the spring of 2020. Originally aimed at asking how COVID would affect the space narrative, we are now focused on shaping that narrative in a positive direction. The reference to the King Arthur story is intentional. As I wrote in my second book, *The New Camelot,* I believe that Arthur's Holy Grail was the unity of the realm of England, and that President Kennedy sought a similar outcome for the people of planet Earth with Apollo—the Apollo astronauts were his Grail Knights!

An additional development is the advent of 2211.world, a website dedicated to the space philosophy field that was launched, again, by Dylan Taylor. As a co-founder and executive contributor, I have added a number of essays to the site. However, the point is not what I have done, but the fact that several diverse individuals have now had their space philosophy work showcased on the site. Multiverse Media, through senior producer Will Henry, has played another important role by turning many of my most recent interviews with Citizen Astronauts into a podcast called "Space Philosophy with Frank White." I am pleased to say, too, that space ethics, a branch of space philosophy, has generated quite a lot of interest since 2012, and I have participated in two panels on this topic, both of which were fascinating. Michelle Hanlon, President of the National Space

Society and organizer of both panels, is planning to create an Institute of Space Ethics, which promises to bring the field to even greater prominence.

Finally, it is worth noting that there is a track on space philosophy at the Kepler Space Institute, and Kepler is creating an *Encyclopedia of Space Philosophy*. Ten years ago, a student could not take space philosophy courses or earn a certificate in space philosophy, but now they can! The Kepler experiment holds great promise, and it will be a center for innovative thinking about space migration far into the future.

In short, the expansion of the space philosophy field since the first edition of JSP has been nothing short of amazing—and highly encouraging. However, resting on our laurels would be a great mistake. As I have asserted from the very beginning, we need an action-oriented space philosophy, not one that is confined to the so-called ivory tower. As humanity evolves outward into the universe, we have an opportunity to begin anew, to correct mistakes of the past and build a positive future. Whether we make a new and better beginning or repeat old behaviors depends largely on what is in our minds, individually and collectively. It depends, largely, on our space philosophy.

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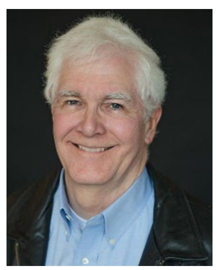

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Frank and his wife Donna live outside Boston, MA.

Editors' Notes: Frank White continues our retrospective exploration of the past ten years. As the author of *The Overview Effect*, he has been a published space philosopher for nearly four decades, so he brings a unique perspective to the discussion. He appeared in the first issue of the JSP and reappeared four more times before this issue. His excitement around the growing interest in space philosophy is energizing and inspiring to us in 2022. We humbly predict that this field of study—and his work in particular—will continue to see an increase in public attention and excitement in the coming years. As we return to the Moon, land humans on Mars, and establish the first commercial space stations we would do well to adopt the message of unity and higher aspirations that Frank advocates. This is only the beginning of human migration into space. ***Mark Wagner and Gordon Arthur*.**

Human Space Activity: The Spiritual Imperative

By Madhu Thangavelu

Religion and scientific pursuits parted company centuries ago, at least in the eyes of the public, most notably in the West during the historical inquisition of Galileo, a devout Christian. He is reputed to have stood by his empirical evidence of the Copernican, sun-centered view of our solar system even under the threat of death by the preferred torture method of the day for heresy: burning at the stake. How dare a commoner employing lowly empirical objective logic challenge the supreme authority, especially on heavenly matters? The church, struggling with the dogma of the time, placed Galileo under house arrest for the rest of his life.

Religion and science have butted heads before and after Galileo, and they continue to seek common ground, but to the layman, the philosophies are irreconcilable. How can we expect a dogma that rests its case at every turn on divine intervention to come to terms with one that employs impeccable, cold, and sterile logic coupled with incremental data gathering to bolster evidence to arrive at its conclusions?

The refined sensitivity of the human mind to the cosmos and environment is clearly evident in the verses of the song called *Laudes Creaturarum* (Praise of the Creatures, also known as Canticle of the Sun), attributed to St. Francis of Assisi. The Sun and the Moon, the most prominent orbs that grace our skies, have a deep-rooted significance in every great religion as well as in science, which employs state-of-the-art technologies to explore and understand the workings of these celestial bodies in our neighborhood, and yet the philosophies could not be further apart. Perhaps that is how it is meant to be? Often, opposing philosophies are needed for the fertile mind to imagine and create new visions.

After all, religion was the primary purveyor of science, and especially astronomy, as is evident in the symbols and images projected in cathedrals and churches and temples all over the world. The heavens belonged to God and religion. Even today, the architecture of religious structures, altars, and prayer spaces around the world aspires to the heavens, and some elaborate geometries are summoned in their planning and design. It is interesting to note that the term “Big Bang,” though coined by Fred Hoyle, referring to the birth of our universe, was conceived by a clergyman, Monsignor Georges Lemaître of Belgium.

People are born into religion and ritual and end their lives in the same way, even though many of us stray away from organized religion and liturgy for most of our lives. Never do we hear of a scientifically accurate christening of a new arrival or send-off for the soul of the departed. Religion and spirituality console and comfort the human soul in a way that science cannot.

Albert Einstein once responded to a question about his religious beliefs by saying that he was utterly in awe and wonderment as nature slowly gave up her secrets and that he was a religious practitioner of science in that respect. Here we see a thought linking religion and spirituality. I think he was referring to spirituality, the essence of all religion, the belief in a supreme power of nature that seems to run the universe with some, yet-to-be-wholly-grasped, supralogical processes, with ultra-mathematical precision to which Vivekananda refers in his lecture on immortality delivered at the Chicago World's Fair in 1893. Even atheists find the power of nature utterly overwhelming.

Religion and spirituality are clearly different, but religion, stripped of all customs and liturgical practice, may reveal an underlying spirituality. It is the essence of wonderment that explorers feel when they are exposed to nature's secrets and subject to awe-inspiring new dimensions in human experience. The great director Peter Brook once said that the human-made world around us is conspiring at every moment to rob us of the sense of awe and wonder that the universe and nature continually presents to us.

Now, this unfathomable power seems to run into trouble with conventional scientific thought all the time; just ask Stephen Hawking or Richard Dawkins. Of course, it is taboo to bring up issues relating to religion or spirituality in modern scientific discussion, though many scientists are privately very spiritual in their beliefs. It is worthwhile to note that doctors practicing modern medicine use spirituality and prayer in the healing process and hospitals have religious or nondenominational spaces just for patients.

A definition that encompasses both of these great philosophies is that proposed by Tolstoy in his essay "Confessions," in which he presents the idea that the greatest science of all is the science of the universe and humanity's place in it. He paints the range of human thought as anchored at one end by theology and at the other by pure mathematics; no reconciliation this, but at least it puts philosophies along a continuum of human thought without artificial walls. John Templeton sought to bring discussion of science and religion closer, and the Templeton Foundation offers annual prizes to those attempting to weave the philosophies together.

Seeking new models for rapidly evolving governance of societies, moving from nationalism to internationalism and beyond, grappling with global issues and the economics of globalization, we seem to be at the threshold of a newly refined era.

Due to globalism, a wholesome new view of our planet and all its contents, the integration of the stewardship of planet Earth and nature in the wake of the effects of climate change, we are coming full circle to embrace the mystical philosophy of transcendentalism, articulated nearly two centuries ago by Thoreau and Emerson, among others. This holistic notion of our planet is being advanced and enhanced by human space activity.[1]

Teilhard de Chardin, a priest, presents the case for the evolution of global consciousness and the arrival of the Omega Point for humanity, and Vladimir Vernadsky talks about the noosphere or the emergence of the global mind, a new layer added to our

[1] The Overview Effect is perhaps a part of this.

planet on top of the geosphere and the biosphere. We live in the Anthropocene epoch, and stewardship of Eden has now become the sole responsibility of our species. The Global Consciousness Project run by Princeton University and projects at the Institute of Noetic Sciences are currently engaged in extending noosphere philosophy. Rapid advances in information technology are changing the scope of our situational awareness, and a global brain with newly evolved and refined sensitivities towards humanity and life, ecology, and the environment is emerging. Vernor Vinge and more recently Ray Kurzweil have talked about the acceleration of technology toward a point referred to as a singularity, projecting visions of merging humanity and technology, blurred, fused, and indistinguishable as separate; human evolution on an accelerated path?

Current trends in machine learning and artificial intelligence (AI) allow us to collect and parse huge amounts of data generated by a horde of systems and sensors that is impossible to distill, let alone act upon, using our innate skills. Tools like DALLE and MidJourney are already revolutionizing the way creative professionals like artists and architects imagine and create new products and buildings. Scientists use these tools to create and study alternative models for research. Doctors and surgeons are starting to depend on AI and robots to conduct lifesaving procedures. And yet we take leaps of faith to arrive at desired outcomes, failing often and succeeding sometimes. Louis Pasteur, when confronted about this scientific quandary, was quick to point out that "chance favors the prepared mind." Is it just chance, or does something deeper and innate drive us forward? Faith? Spirit? Nature?

NASA spends a lot of time and resources focusing on the technology that sustains human space explorers engaged in scientific exploration: a term used to say that these highly specialized professionals are engaged in the pursuit of scientific discovery. It is a very narrow view of human space activity. Space commerce is brimming with ideas beyond the mature and revenue-generating satellite communications field that are awaiting exploitation, among them, beaming solar energy from space and providing extensive refueling operations for outbound vehicles. It is well known among engineers that erecting and deploying large structures such as the ISS or endurance-class spacecraft and space-based solar array farms require on-site human supervision. These crews will find spiritual solace after a hard day's work, looking out at the Earth's disc, from their private quarters in orbit.

As the government astronaut corps around the world continues to shrink, a growing number of human space explorers are wealthy individuals without the professional background or rigorous training of government astronauts. They are seeking to experience spaceflight, to feel outer space in their bellies and souls, and to witness the fragile planet directly while floating above it. The driver seems to be spirituality; physically seeking, experiencing, and appreciating humanity's place in the universe. We call them space tourists. Space adventurers or spiritual tourists, a better term, perhaps?

Space companies like SpaceX, Blue Origin, and Virgin Galactic now have a backlog of people ready to experience space as private citizens. The remark by William Shatner, the indomitable Captain Kirk of the USS Enterprise crew in the long-running TV show *Star Trek* is worth noting. After his short suborbital flight on the Blue Origin New Shepard rocket, looking through those large windows on the capsule, he could see that the blue planet below was all about life, while the still pitch blackness of space, just a few miles above our skies, reminded him of death. Life and death are subjects that are at the heart of the human condition, and the emotions evoked by related events are much better dealt with in the spiritual sphere of our lives. When asked on the Colbert Show about what happens after death, Keanu Reeves said that "the ones who love us will miss us." How do we translate that into scientific terms? Answer: don't even try!

Are there areas of science and technology that weave into religion and spirituality? It appears that human space activity offers a venue to explore possibilities. While robotic spacecraft roam the solar system, sending us intriguing images from worlds afar, the yearning of humanity to be physically present there is what drives NASA and others to pursue space exploration. Without a vibrant human space activity component, NASA may not have a reason to exist.

As the crew lifts off into orbit, though their eyes are on the cockpit monitors and their ears tuned to mission control jargon above the roar of those mighty engines, they are praying for a successful and smooth launch. That is because, despite checks and cross checks and counter checks, despite the best efforts of ground crew and controllers, many things can still go wrong in such a complex system. The monitoring of the final minutes before launch is so rigorous and intense that the entire sequence is handed off from the crew to a set of computers. When your life is in the hands of machines, prayer is important.

Upon arrival at the ISS, the first thing on their minds is to look out at planet Earth. The ISS now sports the Italian-made cupola, a large and exquisite window that looks toward planet Earth, and it is perhaps the most aesthetic component of the entire facility. Of course, it is no secret that the ISS crew spends a lot of its free time just looking out this cupola and marveling at the dynamic colors and drama the Earth gliding below them offers, even as the day becomes night and back again, all in a matter of minutes, as they orbit the planet. As they gaze at Earth through this large cupola, the crew is immersed in a spiritual experience.

I have had astronauts stare me back in the eye when posed the question, how does it feel to be walking on the surface of the Moon? Well, you really have to be there to experience it, they say. Words will not do. It appears their sensory systems are turned up to the highest alertness levels, heartbeats racing like athletes during peak performance, and they are soaking in terabits of information. This rush of data is simply too hard to debrief, in technical terms, prose, or poetry. When faced with such a high, though they are fully aware that it is Newton and Kepler's Laws that guided them there, their minds and souls quickly gravitate toward the scriptures. And human space explorers seek that intense spiritual experience and are willing to risk their lives for it.

Most crews of space missions come back changed forever. This phenomenon is addressed in several books, notably in *The Overview Effect* by Frank White. Astronauts do not see national boundaries, they do not see warring nations, but they do notice the ravages of humanity and industry on the face of the planet.

What they primarily see is a stunningly vibrant planet, lots of blue, aquamarine ocean, virgin white snow-tops on mountain ranges, and scattered puffs of cloud cover, dynamic with flashes of electric blue lightning, as the continents whizz by below them in absolute silence, no one asking them for country of origin or standing in line for visa verification. They see the whole world as one giant harmonious living entity and globalism, that feeling of oneness with nature, takes root in their hearts and souls. A common humanity becomes reality from orbit and cosmopolitanism, the philosophy of acceptance and inclusion of all peoples, the richness and strength of plurality of diverse old cultures and the heritage of customs and shared values become obvious. *E Pluribus Unum* rings loud and clear from orbit.

In worldly affairs and governance, in daily life and commerce, culture and religion, ritual and spirituality all trump science and technology every time. Science and technology are but tools, sophisticated tools of our time, merely used to fulfill human urges and nourishment for our intellect. When faced with the raw wonder and awe of nature, humans always gravitate toward spirituality. That is why when Apollo 8 slipped into lunar orbit, the crew recited from Genesis and why Buzz Aldrin took communion before he stepped onto the Moon.

Yes, perhaps human spaceflight and associated experiences like simulations, aided by advanced gaming systems that use AI and machine learning coupled with augmented and mixed reality, can bring science and spirituality closer together as many more people from various nations, cultures, and walks of life are able to experience space, either directly or vicariously, the sheer awe and wonder of our cosmos and nature. Could this be the raison d'être for the very physical presence on this plane we call Earthly existence. Is technology driving us toward a new dawning of cosmic situational awareness? I suspect, since modern science is reticent on this topic and related matters, the answers to such questions lie deep in the disciplines of spirituality and space philosophy.

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About the Author: Madhu Thangavelu conducts the ASTE 527 Graduate Space Exploration Architectures Concept Synthesis Studio in the Department of Astronautical Engineering within the Viterbi School of Engineering at the University of Southern California. He also teaches the Arch599 Extreme Environment Habitation Design Seminar in the School of Architecture, where he is a graduate thesis adviser. Mr. Thangavelu's educational background is in Architecture (Master's in Building Science, USC School of Architecture 1989) and in Engineering (Bachelor's in Science and Engineering, National Institute of Technology, Calicut, India, 1980). He is also a graduate of the inaugural summer session of the International Space University held at MIT in 1988. Versions of Madhu's master's thesis (conceived during ISU '88 at MIT) entitled "MALEO: Modular Assembly in Low Earth Orbit. An Alternate Strategy for Lunar Base Establishment" were published in several journals worldwide. At USC, he was mentored by and worked as a research assistant and research associate under Prof. Eberhardt Rechtin, Professor of Electrical, Systems and Aerospace Engineering (while he was creating the Systems Architecting Engineering program at USC), considered the chief architect of NASA's Deep Space Network and President Emeritus of Aerospace Corp.

He is a co-author of the book *The Moon: Resources, Future Development and Colonization* (John Wiley & Sons 1999), and the second Springer/Praxis edition was published in 2007, third edition in preparation. He is a former Vice Chairman for Education, Los Angeles Section of the American Institute of Aeronautics and Astronautics (AIAA). He has directed Space Exploration Projects at the California Institute of Earth Art and Architecture. Mr. Thangavelu is also the invited author of the chapter "Living on the Moon" in the Encyclopedia of Aerospace Engineering, a major reference work published by John Wiley and Sons in October 2010, updated in 2012.

He was on the team that won the coveted NASA NIAC Phase 1 and 2 awards consecutively for developing robotic building technologies on the Moon and Mars with PI Prof. Behrokh Khoshnevis. Mr. Thangavelu's concept creation work was greatly appreciated for proposing ideas that pointed to the "leading-edge sensor concept" for return to flight of the space shuttle fleet. Mr. Thangavelu is on the faculty of the International Space University, an international organization that offers advanced interdisciplinary, intercultural, and international training for promising leaders and space professionals. He is the North American coordinator for the International Moon Village

Association and is a Director of the National Space Society (NSS). He is the NSS Vice President and Liaison for NSS India.

Editors' Notes: Dr. Madhu Thangavelu has also been writing about space philosophy since the 1980s, making his perspective another valuable addition to our retrospective on the past decade. He has also appeared in the JSP five times since 2014, and we are grateful for his contribution to this anniversary issue. In this article, he once again explores the spiritual side of humanity's relationship with space, with updates including artificial intelligence, machine learning, and the progress of the commercial space industry. He too strikes themes of unity and hope, advocating for a closer connection between science and spirituality. ***Mark Wagner and Gordon Arthur*.**

Bless Thou Astronauts: A Short History of Faith in the American Space Age 1957–1971

By Grace Jones

Abstract

The space race to the moon brought science and religion to the heart of the Soviet–American Cold War (1945–1991). Many historians have examined the unique cultural and social impact of America's space program, but few have explored the unique role of faith in the space age. This short history explores the unique relationship between science and evangelical history specifically focusing on the religious embrace of space technology and the battle to preserve faith in the divine against the threat of communism and atheism. The history of space technology and religion carry a lasting presence well into our modern age and continue to usher in a spiritual or transcendent experience through the power of spaceflight.

Keywords: Space, religion, technology, faith, spaceflight, history, science, communism.

Introduction

How did the Space Age affect America's belief in the divine? Would humankind's ascent to the stars strengthen or weaken faith? Or was is it possible to unify science and religion in the American space program? Many would be shocked to know the unique role of faith in the US space race to the moon. The apostles of the Apollo program envisioned a world in which science and religion could work together. This article explores the overall impact of human space exploration and the Protestant Christian (evangelical) church exploring the following themes. First, this section explores the implications of human space exploration on the evangelical church in the Cold War. How did space exploration impact faith, and would it displace it? This second section observes the collaborative relationship between science and religion looking at the incredible lives of two theologians: Rev. Carl McIntire and Rev. John Stout, who sought to persuade NASA to utilize faith during manned human spaceflight missions specifically in the Apollo Program. The third and final section looks ahead to the future of spaceflight in our modern technological era and its interactions with religion and spirituality.

Paradise Lost and Found

The race to the moon had more religious nuances than we might realize. Many would be surprised to learn that the earlier days of American manned spaceflight was largely dominated and supported by Christian Protestantism.[1] For centuries, the relationship between science and religion has often been thought of as historically incompatible.

[1] Kendrick Oliver, *To Touch the Face of God* (Baltimore: Johns Hopkins University Press, 2013).

However, the impact of human space exploration proves that this is *not* the case. With the launch of the Soviet satellite, Sputnik 1 (1957), some evangelical pastors proclaimed, "Don't be surprised if He (Jesus) comes today," viewing the eerie silver object as a prophetic sign of the coming apocalypse.[2] Every pulpit remarked on the complexities of Sputnik; they questioned whether it was it dangerous—even blasphemous to God. For some believers, the satellite challenged divinity. Some evangelicals commented that Sputnik was a "frightening toy in the hands of childlike men" who were without religion and morals.[3]

> And here we have our Sputnik
> No secret: the newborn planet
> Is modest about its size
> But this symbol of intellect and light
> Is made by us, and not by the God
> Of the Old Testament.[4]

But Sputnik was only the beginning. The Space Age forever challenged the traditional views of heaven with the launch of cosmonaut Yuri Gagarin on Vostok 1 (1961). Historian Kendrick Oliver suggested that many Christians thought the Russians desacralized the heavens due to their "lack of belief" in the divine in his book *To Touch the Face of God*.[5] Some theologians noted that humankind was as close to God as it had ever been, but such a divine experience would go unrecognized by the Soviet nation. Sacred space had been invaded by the USSR and held captive by Gagarin. While many felt that the USSR had invaded sacred space, others embraced the idea of space travel because it "proved the existence of the divine."[6] Despite some growing fears of a world that would forget heaven, many saw the space race as an opportunity to reclaim God as the divine Creator.[7] Charles Halff's famous book *The Bible and Space Travel* encouraged Americans of faith to welcome a divinely inspired era of human spaceflight. Fighting against the communists meant embracing a "techno-religion" of sorts.[8] Maintaining religious devotion, in this era, also meant keeping faith in science and technology. Historian David Noble writes in his book *The Religion of Technology* that the production of new technologies and scientific pursuits expressed the redemption of humanity from the fall of mankind as described in

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[2] George W. Cornell, "Satellites Stir Debate of Science vs. Religion" *Washington Post and Times Herald*, February 4, 1958.
[3] Paul Dickson, *Sputnik: The Shock of the Century* (London: Walker, 2001), 114–15.
[4] "Religion: Not by God," *Time Magazine* 87, no. 14, 1975.
[5] Oliver, *To Touch the Face of God*, 10.
[6] Martin Heinecken, *God in the Space Age* (Philadelphia: John C. Winston, 1959).
[7] Jonathan Herzog, *The Spiritual–Industrial Complex* (New York: Oxford University Press, 2011).
[8] David Noble, *The Religion of Technology: The Divinity of Man and the Spirit of Invention* (New York: Penguin Books, 1997).

the Book of Genesis.[9] Kendrick Oliver suggests that despite some initial resistance toward space age technologies, the prospect of spaceflight brought about a transformative era of divinity and redemption. Spaceflight symbolized an ascending motion toward heaven. Both Noble and Oliver stated that spaceflight (at least in the United States) "owed much to religious archetypes and sensibilities."[10] Increasingly, science and technology remained indebted to religion as faith seemed to be a primary tool in technological innovation. Many working in the Apollo program found no conflict between faith and science. The prospect of a moon landing strengthened faith as technological growth persisted. Explorations of God's celestial creation did not challenge divine supremacy.

Apollo's Apostles

As NASA worked tirelessly to launch American astronaut Alan Shepard into space, two theologians, Rev. Carl McIntire and Rev. John Stout, worked alongside them. McIntire believed that technology was crucial to the survival of faith and sought to form a space-based religious campaign to encourage believers in Christ not to dwell on old science vs. technology debates, but instead to embrace a future dominated by space travel. He often discussed how technology could bring about a Christ-centered America and how NASA's missions (against the Communist nations) would solidify belief in creationism.[11] In the mid-1960s, McIntire opened a large hotel on Cape Canaveral called "Gateway to the Stars" to invite enthusiastic Christians to explore the word of God through his yearly Bible conference and to witness the "spectacular accomplishments in spaceflight: factories, labs, communities, experiments of every conceivable kind … as [humanity] prepared to live permanently in the sky."[12] He compared the flaming rockets and sputtering chariots of spacemen to biblical prophecy and often encouraged astronauts to incorporate religious ritual into their missions. The Apollo 8 (1968) reading of Genesis thrilled McIntire and his many supporters; this event only strengthened his mission to use NASA's resources for the glory of God—despite pushback from some American activists including Madalyn Murray O'Hair.[13] The reciting of the biblical creation story was broadcast to televisions in nearly every home in America and around the world. McIntire believed that the "moon would never be the same," and the Genesis story would forever ring in the ears of all those who witnessed the incredible journey of the Apollo 8 astronauts. He strongly believed that those who came to Cape Canaveral could walk in the presence of the Lord as astronauts ascended into heavens.

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[9] Noble, *The Religion of Technology*.

[10] Oliver, *To Touch the Face of God,* 9.

[11] Carl McIntire, "Creation and Revelation Command Cape Canaveral," *Christian Beacon*, October 24, 1974, 1.

[12] Carl McIntire, "Gateway to the Stars: Pamphlet for Cape Canaveral Bible Conference," n.d.

[13] Madalyn Murray O'Hair supported atheism and the separation of church and state. After the Apollo 8 Genesis reading, O'Hair filed a lawsuit against NASA; however, the case was rejected due to a lack of jurisdiction—yet the challenge impacted the way NASA handled future interactions with religion.

As McIntire worked to bring his loyal followers to Cape Canaveral, another clergyman and scholar was working to bring the Word of God to heaven itself. Many are unfamiliar with the incredible history of NASA's chaplain to the astronauts, Rev. John Stout. In the midst of the space race, the young scientist from Texas accepted his role at NASA under one condition: that he could use his theological degree to motivate the astronauts who trained daily for manned lunar missions spiritually. Stout was well known for his scientific expertise as an engineer, but in the tragedy of Apollo 1 he would become something far greater. After the death of his dear friend Astronaut Edward White, Stout sought to honor his memory and legacy by organizing the Apollo Prayer League in 1967—a group dedicated to praying for the safety of the astronauts and all manned-spacecraft missions.[14] Stout's versatility in science and faith and his admiration for White's belief that "space travel brought humanity closer to God" inspired him to bring the Bible to the lunar surface.[15] In 1971, utilizing microfilm technology the Lunar Bible landed successfully on the moon during the Apollo 14 mission.

Both McIntire and Stout concluded that America's space program revitalized faith in the divine. Space travel would only strengthen faith. Citizens across the United States wrote thousands of letters to both Stout and McIntire about their efforts in securing religion and the space program. For some, the unification of science and faith at such a transcendent level renewed their faith in God—as many felt they could also experience what the astronauts spiritually encountered during spaceflight.[16] The blessing of space technology forever altered how believers could experience God—whether it was on the grounds of Cape Canaveral or in the comfort of their homes. Science did not displace faith. Instead, it adopted religion and made it physically transcendent. Both McIntire and Stout believed that the American space program declared the glory of God and celebrated humanity's scientific innovation.

Sacred Space

The unique story of spaceflight and religion during the Soviet–American Cold War plays an interesting role looking ahead to the future of space travel and new posthuman capabilities.[17] Now that we have briefly touched on the role of religion and science during the space race, what will space and religion look like in future missions to the moon and beyond? The new religion of space exploration points to the sublime through the powers of engineering. Kendrick Oliver recounted in *To Touch the Face of God* that many Apollo

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[14] Astronaut Edward White stated to Stout that he wanted to take his Bible into space as he prepared for the Apollo 1 mission.

[15] Carol Mersch, *The Incredible Reverend Stout: Presidents, Astronauts, and the Woman He Loved* (Fayetteville, AK: Pen-L, 2021).

[16] This is similar to the Overview Effect.

[17] Posthumanism is a concept that originates in the field of futurology or philosophy that seeks to look at going beyond the present state of humanity. In other words, it looks at how humans will evolve in the future as technology continues to advance.

astronauts, despite their hostile environment, still reported feelings of divinity while walking on the lunar surface. For some, it was the familiar feeling of the Overview Effect, and for others, it was a transcendent experience with God.[18] The future of human space exploration beyond the moon will include an inclusive spiritual perspective—though it may shift from a predominately Christian outlook. It is still an unavoidable fact that the nature of spaceflight induces an experience like no other.

As scientists speak of a posthuman future in which technology reshapes human life on earth, it is discernable that the future of space technology will also have a lasting impact on the human mind and belief systems. For some, space itself could represent its own religion with no influence from the divine; others may find comfort in taking their religion to outer space. Looking toward a posthuman era, the relationship between space and religion will inevitably draw from the historic past of the Apollo era as space exploration fits several characteristics of religion. It is paired with curiosity about the unknown and the desire for meaning in the universe. Humanity has always looked to the stars for spiritual meaning and guidance; it is only natural that we will continue to look for them even among the stars.

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About the Author: Grace Jones is a historian and writer working for the College of Arts and Sciences at Texas A&M University in College Station, Texas. Her academic focus is the history and philosophy of religion and technology. She currently holds an MA in History and a BA in English. Grace also works as a Human Space Flight Specialist for The Aerospace Corporation. She has worked on various space-related projects for Aerospace, including lunar-based missions. In her spare time, she is an advocate for the development

[18] The Overview Effect is a cognitive shift in awareness reported by astronauts while in spaceflight. Research has concluded that the effect is similar to a transcendent or awe-inspired state brought about by the process of viewing Earth from space, reshaping the perception of beauty or producing overwhelming emotion. This experience can be transformative and influence the belief system or religion of an individual during space travel.

of space-based education, career diversity, and interdisciplinary research in the broad fields of liberal arts.

Editors' Notes: Our retrospective continues with an article by a first-time contributor, space historian Grace Jones. Like Thangavelu, Jones addresses the role of spirituality in the space age … particularly the role of evangelical religion in the United States during the cold war space race. From poetry about Sputnik to projections of a posthuman future, this historian gives us a lot to think about as we begin to look forward to the next ten years of space philosophy. ***Mark Wagner and Gordon Arthur*.**

Evolving Markets, Capabilities, and CONOPS for Economically Competitive Space Solar Power

By John C. Mankins

Abstract

Several new capabilities, market opportunities, and concepts have emerged during 2021–2022 that will improve prospects for economically feasible, hyper-modular space solar power (SSP) systems. These include launch options, carbon-driven pricing, and more sustainable concepts of operations (CONOPS) for both space and ground segments. First, SpaceX has announced expected launch rates and costs, and an operations schedule for its planned Starship+ Heavy Booster launch system. Other countries and companies, including Blue Origin, China, Japan, the European Space Agency, Honda, and Rocket Lab in New Zealand have also announced plans for reusable launchers. It now seems inevitable that low-cost space access is coming before the end of this decade. In addition, multiple countries have announced ambitious carbon net-zero goals. However, in late 2021 at the COP26 meeting in Glasgow, UK, it was evident that there is no easy solution to carbon emissions driving climate change. Thus, carbon policy-driven pricing on low emissions technologies, such as SSP, seems likely, which will dramatically increase their economic attractiveness, perhaps reducing their perceived risks Lastly, there is continuing concern regarding orbital debris and operations risks to SSP. There are several new concepts and CONOPS that can improve expectations for future SSP systems.

Keywords: Space solar power, SSP, IAA, SPS–ALPHA

Introduction

Several new capabilities, changing market opportunities, and novel concepts have emerged during 2021–2022 that will positively impact prospects for economically feasible, hyper-modular space solar power (SSP) systems. These include (1) launch options, (2) carbon-driven pricing, and (3) more sustainable concepts of operations (CONOPS) for both the space and the ground segments. First, expected launch rates and costs, and a schedule to begin operations have now been announced by SpaceX for its planned Starship+ Heavy Booster reusable two-stage-to-orbit (TSTO) launch system. At the same time, a number of other countries and companies, including Blue Origin (from prior planning), China, Japan, the European Space Agency (ESA), Honda, and even Rocket Lab in New Zealand have all announced plans to follow with their own reusable launchers. It seems now inevitable that truly low-cost space access is coming—and before the end of this decade. In addition, ambitious carbon net-zero goals have been announced by multiple countries during the past two years or so. However, in late 2021 at the COP26 (Conference of the Parties) meeting in Glasgow, Scotland (UK) it was evident that there is no easy solution to the challenge of carbon emissions driving climate change. As a result, the prospects now appear likely for carbon policy-driven pricing on low emissions technologies, such as SSP, that will dramatically increase their economic attractiveness, making it more likely that the perceived risks in such new technologies can be overcome. Lastly there is continuing concern regarding orbital debris and operations risks that must be addressed by SSP proponents for SSP to be realized. There are a number of new concepts and CONOPS that can improve expectations for the operations of future SSP systems.

This paper reviews the changes of the past several years, and frames an integrated view of how they impact the technical viability and economic viability of modular SSP systems such as SPS–ALPHA (solar power satellite by means of arbitrarily large phased array).

SPS–ALPHA Overview

SPS–ALPHA (Figure 1) was first studied under a NASA advanced innovative concepts program Phase 1 concept study published in 2011.[1] Further development of the concept has occurred since that study, of course.[2] The following paragraphs provide an overview of the concept as it stands now.

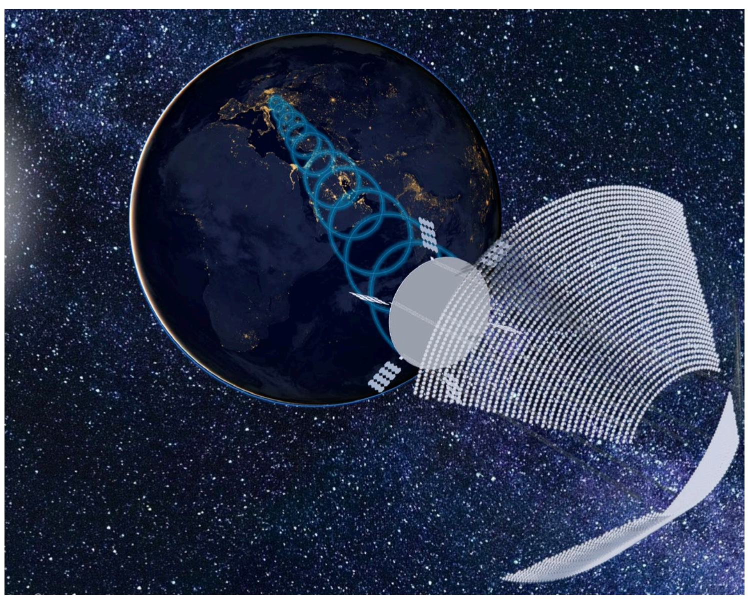

Figure 1: SPS–ALPHA transmitting energy to Europe at midnight. (Concept and image courtesy John C Mankins.)

[1] John C. Mankins, *SPS–ALPHA: The First Practical Solar Power Satellite* (Washington, DC: NASA Institute for Advanced Concepts, 2011).

[2] John C. Mankins, *The Case for Space Solar Power* (Houston: Virginia Edition, 2014).

Core Technical Aspects

The core technical aspects of the SPS–ALPHA concept have remained unchanged, although various specific aspects of the design have evolved—from the Mark 1 to the Mark 2 and finally to the Mark 3. These involve both component- and architecture-level features. The most important component-level aspects include the following.

(1) First, the use of microwave frequencies (i.e., in the range from 2 to 10 GHz) for wireless power transmission to achieve all-weather operations and a simple very high-efficiency rectifying antenna (rectenna) receiver.

(2) Also, a reliance on solid-state power amplifiers and retrodirective phase control to provide precision electronic pointing of the microwave wireless power transmission from transmitter to receiver—essentially trading phase information and control for physical rigidity and the pointing of the transmitter.

(3) In addition, the presumption of high-efficiency radiation-tolerant photovoltaic arrays to convert sunlight into electrical voltage—feeding into a local, low-voltage power management and distribution system and driving the solid-state power amplifiers.

(4) A reliance on the capabilities of modern electronics and software—including systems autonomy, sensors of various sorts, onboard data processing and storage, resilient and reconfigurable network computing, etc.—to enable the platform to self-assemble, self-repair and self-reconfigure without the intervention of either astronauts or substantial external infrastructures.

(5) Use of designs, materials, and components to enable distributed local mitigation of what would normally be system-level disturbances or effects—including disposal of waste heat and compensation for and/or suppression of structural vibrations.

(6) Use of high-efficiency propulsion systems for attitude control and to assist with structural controls and vibration suppression, including both electric thrusters involving benign propellants (e.g., Hall thrusters) or solar pressure (e.g., solar sails).

In addition, the most important architecture-level aspects (enabled by the component technologies above) include:

(7) The employment of a hyper-modular architecture—now well-known in SPS circles, but first introduced by SPS–ALPHA—which enables exceptionally large platforms to be assembled from very larger numbers of relatively very small, mass-produced modules.

(8) Employing heliostats (i.e., reflectors) on a relatively low-mass structure to redirect incoming sunlight adaptively toward the photovoltaic array—thereby enabling a

planar hyper-modular energy conversion array to deliver power to a remote receiver almost continuously, rather than only when the alignment is correct.

(9) Use of a planar mesh antenna as the receiver (aka a rectifying antenna, or rectenna) on shore or off at an elevation of at least 3–4 meters, and up to 5–10 meters—allowing dual use of the area underneath. For example, allowing the use of land underneath the rectenna for agriculture. Moreover, if lighter in color (i.e., with a higher albedo) or reflecting, then there can be a net a cooling effect based on the fill-factor of perhaps 15%–20%.

(10) Integration of energy storage systems at the site of each receiver, allowing a single SPS to deliver continuous power to multiple sites through the use of the local energy storage for time sharing. For example, 2 GW of delivered power from a single SP–ALPHA can be shared among multiple ground sites through the use of energy storage.

SPS–ALPHA Space Segment[3]

As Figure 2 shows, the SPS–ALPHA space segment comprises four major elements: (A) the energy conversion array, (B) the heliostat reflector array, (C) connecting structures between (A) and (B), and (D) additional modules, such as attitude control modules.

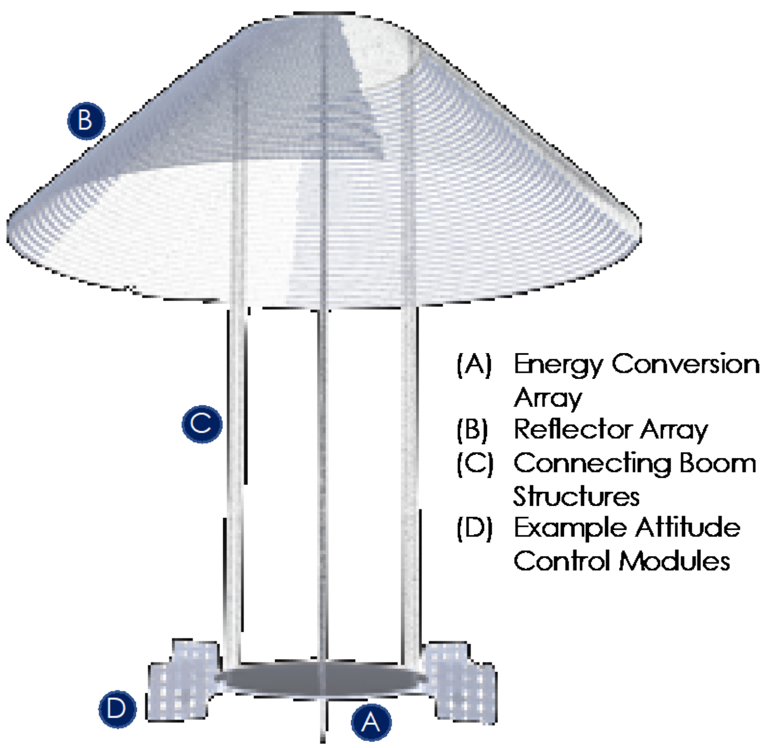

Figure 2. SPS–ALPHA (Mark-3) Space Segment

[3] The discussion here addresses the SPS–ALPHA Mark 3 version, first presented in 2020.

Supporting Infrastructure

The single most critical element of supporting infrastructure for any SSP system—including SPS–ALPHA—is, of course the Earth-to-orbit (ETO) transportation system. The single most important development relative to enabling economically viable SSP is the emergence of reusable and affordable boosters for ETO transport, beginning with the Falcon 9 reusable launcher of Space Exploration Technologies, Inc. (SpaceX). At present, SpaceX is developing a still lower cost launch option: the Starship and Heavy Booster option, with public statements suggesting that the ETO cost that might be achieved by this system will be below $100–$200 per kilogram to LEO.

Moreover, there are several other reusable launch vehicles under development. They include the New Glenn launcher of Blue Origin, as well as reusable launchers from New Zealand's Rocket, Japan, China (a new version of the Long March 9), and by the European Space Agency (ESA). Altogether, there may be as many as 5–8 reusable launchers operating by the end of the 2020s. This suggests rather strongly that that there will be a very competitive market for SPS launch contracts by 2030.

SPS–ALPHA Ground Segment

As noted above, the ground segment of the SPS–ALPHA concept includes a large rectenna receiver, associated energy storage, and ground control systems.

Ground Receiver

To achieve retrodirective phase control, the ground receiver for SPS–ALPHA will comprise two primary systems: the rectifying antenna (rectenna) and a pilot signal system (RF frequency source and transmitting antenna). The ground receiver for a system using a frequency of 2.45 GHz and delivering approximately 2 GW (with a transmitter of 1,800 meters in diameter) from GEO would be about 6,000 meters in diameter on the equator directly below the platform (i.e., an area of 28 km^2). This size reflects a maximum interception of the arriving microwave transmission of about 96%. However, because it is a Gaussian distribution, intercepting 50% of the microwave transmission would require an area less than one quarter as much.

The required receiver diameter for a given beam interception increases with increasing distance from the point directly below the SPS, with the cosine of the changing angle, so that at the maximum angle the diameter might increase to a maximum of about 8.5 km (an area of 56.5 km^2). This compares very well with typical land areas required for hydroelectric power plants, as illustrated in Figure 3 for 2,000 MW SPS–ALPHA at 27 km^2-to-56.5 km^2, versus the case of the 500 MW (average) Hoover Dam in the United States at 640 km^2 (reservoir area) and 435,000 km^2 (catchment area).[4]

[4] See en.wikipedia.org/wiki/Hoover_Dam.

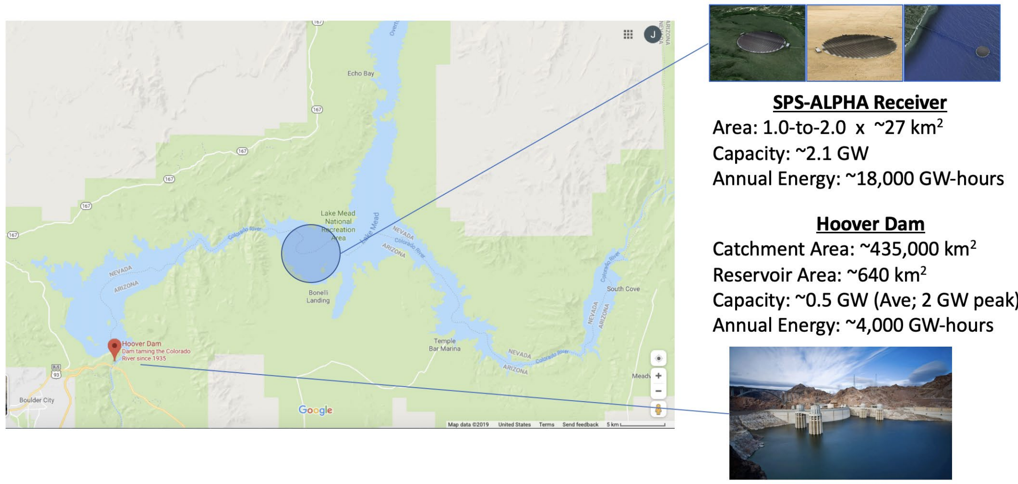

Figure 3. Example Rectenna Area @ 27 km^2 Compared to Area of the Lake Mead Reservoir for the Hoover Dam

Energy Storage

Energy storage is required to achieve nearly continuous power delivery from a GEO-based SPS–ALPHA system due to the periodic shadowing of the platform in March and September (the vernal and autumnal equinoxes). Lasting for about two weeks—the maximum duration of the shadowing is some seventy minutes at the mid-point of the period—which provides a minimum size for the energy storage system.[5] The total energy storage required for continuous power delivery would therefore be about 2.3 x 10^6 kWh.

By sharing the power delivered from a single 2.1 GW SPS among three ground receivers with energy storage at this scale, each might deliver 700 MW of power continuously. Alternatively, one might use the power delivered from an SPS to supplement terrestrial solar power systems.

Ground-Based Mission Control

A third major element of the SPS–ALPHA ground infrastructure is a ground control system, where a single such mission control center might very well be used to operate multiple largely autonomously self-assembling and maintaining solar power satellites. The mission control centers that are now in use for mega-constellations (e.g., Starlink, Kuiper system) may be useful models for this purpose.

Prospects for Low-Cost Deployment

There are three essential elements required for low-cost deployment of SPS systems (space and ground segments). These include very low-cost ETO, affordable and timely

[5] G. Maral and M. Bousquet, *Satellite Communications Systems: Systems, Techniques and Technology*, 4th ed. (Chichester, UK: John Wiley & Sons, 2004).

transportation from LEO to the desired operational orbit for the SPS (i.e., typically geostationary Earth orbit, GEO) and cost-effective assembly, repair, and maintenance of the SPS platform. As noted above, recent advances in reducing ETO costs through the development of affordable, reusable boosters have dramatically advanced the prospects for cost-effective SSP.

In addition, there have been dramatic advances in the capabilities of various morphologies and markets related to robotics in the past two decades—from robots as simple as household cleaning systems to larger and more capable warehouse robots to a variety of novel body types (and sensor packages) developed for emergency or combat operations. All in all, the prospects for affordable and resilient SSP assembly, repair and reconfiguration have made great strides.

Sustainable Concepts of Operations

A central issue that is often raised *vis-à-vis* the CONOPS for SSP systems is that of disposal at the end of life for the space segment. In the case of traditional GEO satellites (typically communications satellites), disposal of failed platforms is typically handled by reserving a small amount of propellant and using it to boost the soon-to-be-dead spacecraft out of GEO and into a so-called graveyard orbit—where it remains forever. Of course, this solution is problematic going forward: orbital debris has been identified as an increasing concern in LEO, and parking ever-larger numbers of defunct satellites weighing a few tonnes in mass in orbits near GEO can only lead in time to collisions and more debris. How much less acceptable then to suggest taking the same route with an SPS weighing thousands of tonnes?

In the case of highly modular solutions such as SPS–ALPHA, it has been proposed that there would be no singular end-of-life event; rather, the modules of such platforms would fail occasionally—a few each year—to be replaced or repaired. The platform as a whole would continue indefinitely; however, what about the modules that fail each year?

The economic modelling developed for SPS–ALPHA assumes a failure rate of about 3% per year. (As a result, the effective lifetime of the SPS–ALPHA may be viewed as 33 years; however, operational capability represented by the platform will continue indefinitely.) Consequently, for a 7,500,000 kg platform, the annual total dead module disposal would be a mass of about 225 tonnes per year.

An approach that would be sustainable over a long period might be to remove these modules from the operational orbit (GEO) to a permanent graveyard at the Earth–Moon Libration Point L3. This location, which is not being considered for lunar operations (as is EM L1), or for large space habitats (as has been EM L5), is accessible with a relatively modest additional investment of energy at about 1,500 m/s. (Note that this is the same delta-V required for 30 years of station-keeping in GEO at 50 meters-per-second over 30 years.)

Markets and Carbon Net-Zero Goals

The United Nations Intergovernmental Panel on Climate Change COP26 was held in Glasgow, Scotland in the Fall of 2021. This meeting and other studies established as a goal for global industrial civilization that the consumption of fossil fuels must be reduced to a near net-zero level by the middle of the century and that the greenhouse gas emission-driven global warming effects must be held below 1.5°C (about 3°F). Recent announcements (October 2022) from the United Nations suggest that this goal cannot now be achieved; a new objective (i.e., target maximum acceptable temperature increase) has not yet been announced.

Conclusions

A number of critically important changes have occurred during the past several years in the field of SSP in general and SPS–ALPHA in particular. This has framed an integrated view of how these changes impact the technical viability and economic viability of modular SSP systems—in particular the current version of SPS–ALPHA, which was the hyper-modular SSP capable of 24-7 operations published about a decade ago. Although a variety of configurations are possible, this approach to SSP is at the present time the most promising in terms of prospects for both effective and resilient deployment and affordable and cost-effect power generation.

SSP has become a far more serious candidate for a carbon net-zero energy option for global markets during the past handful of years. There are several reasons: the reduction in launch costs due to emerging reusable boosters; advances in key technologies such as robotics, high-efficiency electronics, and others, and the prospects for low-cost space hardware demonstrated by new, affordable mega-constellations. These have been proven to be directly applicable to the affordable and timely development of SSP through novel, hyper-modular concepts such as SPS–ALPHA. A new option for disposal of failed SPS–ALPHA modules has been proposed: the EM L3 point on the far side of the Earth from the Moon.

Ongoing developments (e.g., in the UK, Japan, China, etc.) and prospects for future programs will determine whether and what SSP concepts continue to emerge and evolve.

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About the Author: John C. Mankins is President of Artemis Innovation Management Solutions LLC and of Mankins Space Technology, Inc., and a Director of Solar Space Technologies Ltd. Pty. He is Vice President of the Moon Village Association, and is a Dean and Professor at the on-line Kepler Space Institute.

While at NASA and JPL, Mankins held numerous positions, including in the Office of Space Flight, Assistant Associate Administrator for Advanced Systems (acting), and Chief Technologist for Human Exploration and Development of Space. He received the NASA Exceptional Technology Achievement Medal.

He holds a BS (Harvey Mudd College), an MS (UCLA), and an MBA (Claremont Graduate University). He is a member of the American Association for the Advancement of Science, the IEEE, Sigma Xi, and the International Academy of Astronautics.

Mankins is known for writing the definitions of the Technology Readiness Levels and as the world's leading expert in the field of Space Solar Power.

Editors' Notes: John Mankins has been working toward the promise of Space Solar Power for decades, and he wrote an authoritative book on the subject in 2014.[6] This article is his first contribution to the *Journal of Space Philosophy*, and it's a timely one. With the recent advances he describes, the market for Space Solar Power has been projected at between $300 billion[7] and $1 trillion by the end of the decade.[8] It may be as inexpensive as 20% the cost of fossil fuels by 2040.[9] This source of power has the potential to revolutionize the world's economies in the coming decade, and John Mankins's work is leading the way. ***Mark Wagner and Gordon Arthur.***

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6 www.amazon.com/John-Mankins-Space-Solar-Power/dp/B00N4IXV06/.

7 www.globenewswire.com/en/news-release/2022/09/06/2510112/0/en/Solar-Power-Market-Size-Worth-USD-293-18-Billion-Globally-by-2028-at-6-9-CAGR.html.

8 www.alliedmarketresearch.com/space-based-solar-power-market-A07358.

9 www.nextbigfuture.com/2020/12/future-2040-solar-will-be-five-times-cheaper-than-fossil-fuel-electricity.html.

Rise of the Chinese Space Program: How China Came to Rival the United States in Space Technology

By Rebecca Schembri

Abstract

This article defines the major American diplomatic moments that spurred China's space program from 1950 to 2022. Since ancient times, Chinese astronomers have produced accurate depictions of the cosmos. In the Dark Ages, the Chinese invented the world's first rocket, and within just six years of establishing the People's Republic of China, the Chinese government reignited its passion for space exploration and leadership. Seventy years later, China achieved space superpower status. This was not due to a Chinese quest for space, however. The main reason China made its space program a priority is because of a security dilemma in which US satellites, missiles, and spacefaring technologies—coupled with American distaste for China—threatened China's well-being. China wanted sovereignty, safety, and due respect; it wanted out of America's shadow.

Keywords: China, NASA, Wolf amendment, Qian Xuesen, space, moon, Sino–American, Artemis.

Introduction

The United States has historically withheld respect from China's space program. Although international scholars have written that China deserves equal recognition for its space technology, American scholars either do not share that sentiment or report that the United States does not share that sentiment. According to America, China's natural place was always under US dominance.[1] In 2005, Marcia Smith, a senior non-partisan analyst, reported to Congress that the United States "laugh[ed]" at space program rivalry between the two countries, and she noted that the United States refused to believe China could surpass American supremacy in space technology.[2] In 2008 Kevin Pollpeter, a US military analyst, reported that China was progressing but that China had neither "the foundation nor the resources" to conduct a space race with the United States.[3] Both Smith and Pollpeter either noted or conveyed America's lack of care for Chinese space power. These and other analysts reiterated America's long-time suspicion of China stealing information to build its space program, stating that China was militarily motivated, and that China was

[1] Dong Wang, *The United States and China: A History from the Eighteenth Century to the Present*, 2nd ed. (Lanham: Rowman & Littlefield, 2021).

[2] Marcia S. Smith, "China's Space Program: An Overview," Congressional Research Service Report, Library of Congress, 2005, 6.

[3] Kevin Pollpeter and the Army War College, "Building for the Future: China's Progress in Space Technology During the Tenth 5-Year Plan and the U.S. Response," Strategic Studies Institute (Carlisle Barracks, PA: US Army War College, 2008), 51.

incapable of matching—and especially surpassing—American strength in space leadership.[4] The American mindset was that China could not bypass American space supremacy.

Historian Dong Wang reported on this anti-Chinese bias in her book *The United States and China: A History from the Eighteenth Century to the Present*. In it, she uncovered a dark history of Sino–American relations in which America pressed upon China acts of humiliation, unfairness, exclusion, and exploitation for over one hundred years.[5] She noted that America historically believed that "China would never become a superpower because China [was] unstable and weak," and that the United States maintained that China was neither important nor influential.[6] This old, cultural attitude began with unfair tariff treaties and exclusionary laws in the 1800s, and by the 1950s it had permeated into US space relations with China, as Smith would one day testify that even in periods of rapprochement the United States excluded China from collaborating on space missions.[7]

However, many international scholars applauded China. They wrote that China's space program was on similar ground to the American program, and it always had been. An Indian space agency scientist and scholar whose main role included assessing China's space program and China's space military strife with the United States wrote on the internal and external factors that shaped China's space progress.[8] In his book, S. Chandrashekar explained that although China did not put the first human in space (like the USSR) or the first human on the moon (like the United States), the Chinese came in at the heels of its competitors in space technology.[9] Despite intense political upheaval in its early years, the Chinese space program remained strong.[10]

Likewise, spaceflight scholar Brian Harvey, who wrote the authoritative book on the rise of China's space program, identified American scorn for China's legitimate successes. He wrote:

> many in the western media who ought to know better responded to Chinese space developments with a mixture of puzzlement, patronizing put-downs, and dismissal. If it worked, the presumption was that it must have been

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[4] James Oberg, "Testimony of James Oberg: Senate Science, Technology, and Space Hearing: International Space Exploration Program Status Report," Senate Committee on Commerce, Science, and Transportation, Washington, DC, April 27, 2004, 2.

[5] Wang, *United States and China*, xiii–xix (late 1800s: China submits to US trade norms); xx (United States forces its values); 53 (exclusionary laws deny rights to Chinese immigrants); 62–63 (hate crimes); xxi (United States refuses to recognize Chinese government until 1970).

[6] Wang, *United States and China*, xxiii, as cited by David Shambaugh, *China Goes Global: The Partial Power* (Oxford: Oxford University Press, 2013), x and 6.

[7] Smith, "China's Space Program," 4.

[8] S. Chandrashekar, *China's Space Programme: From the Era of Mao Zedong to Xi Jinping* (Singapore: Springer, 2022).

[9] Chandrashekar, *China's Space Programme*.

[10] Chandrashekar, *China's Space Programme*.

> stolen or developed for sinister military purposes. There remains an extraordinary reluctance to concede to the Chinese the credit of having created, designed, and built their own equipment. This is a problem not peculiar to the space program, for the west often forgets how China pioneered so many things, from medicine to mathematics.[11]

According to Harvey, America refused to accept that a communist China could be on equal ground with the United States, a democratic nation.

Moscow University scholar Evgeniia Drozhashchikh concurred with Chandrashekar and Harvey. Her assessment of China's space program history was that China built a world-class program, bartered for any technology it was lacking, and deservedly became a space superpower. According to Drozhashchikh, the Chinese space program was efficient and powerful, yet historically undervalued by America.[12] These perspectives from non-American scholars who respected China, and from American scholars who did not, give insight into China's dedication to equality in space technology, and to the country's disappointing rejection by its American counterpart.

This article adds to the claims that the United States was in denial of China's ability to succeed in space power. In addition to America not ceding China its due respect in aerospace advancement, because of discriminatory American acts toward China, China would eventually match the United States in space power and would become America's greatest space rival. Certain defining moments spurred China's space program, and these aligned with the American treatment of China. The historical backdrop of American abuse of China since the mid-nineteenth century formed the overarching sentiment between a hubristic, powerful America and a modest, unsuspecting China. It is against this scenario that five defining moments in the Sino–American timeline emerge.

First was the Red Scare in the 1950s, when Chinese nationals were persecuted in America under suspicion of communist sympathy.[13] Many returned to China resolved to serve their mother country and to abandon America forever. This drew a hard line between the two countries, and it made the Chinese determined to escape American dominance. The second defining moment was external: in the 1960s the United States and the Soviet Union raced to exceed each other in space technology, and China found itself in a security dilemma where, based on its past relationship with the United States, it felt forced to manufacture arms or be safety-compromised. In 1971 China admitted that it was testing nuclear weapons to "break the monopoly of certain superpowers."[14] This

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[11] Brian Harvey, *China in Space: The Great Leap Forward*, 2nd ed. (Chichester, UK: Springer, 2019), xi.

[12] Evgeniia Drozhashchikh, "China's National Space Program and the 'China Dream,'" *Astropolitics* 16, no. 3: 175–86.

[13] Robert Ferrell and Peter Szatmary, "The Villains of the 'Red Scares' of 1950," *Phi Kappa Phi Forum* 90, no. 3 (2010): 10–11.

[14] US Department of State, "Memorandum of Conversation," Office of the Historian, July 10, 1971, history.state.gov/historicaldocuments/frus1969-76v17/d140.

threat drove China to make space technology a national priority and to keep much of its program secret.[15] The military space power of the United States—which ultimately won the space race against the Soviet Union—threatened China.

The third defining moment was tripart and occurred between 1996 and 1999. When China began to emerge with competitive space technology, the United States accused China of stealing information.[16] Then the United States formed a Congressional inquisition that accused Chinese people in America of decades of spying.[17] Finally, the United States launched an international space station and prevented China from participating. In 2003, China sent humans into space, but America had already taken steps to marginalize China from space advancement. The fourth defining moment came in 2011, when the US Congress codified a US ban on all Chinese collaboration with NASA, including Chinese students and space professionals who specialized in space technology.[18] This caused an upset within the scientific community, and it caused China to gain non-American supporters.[19]

The fifth defining moment happened in 2017 when the United States disregarded international law and announced its bilateral plan to territorialize the moon.[20] In effect, the Artemis moon program would maintain US leadership and supremacy in space, and it would use other countries as cushion consent, protecting it from international legal backlash.[21] This apparent enclosure movement was the final flashpoint that propelled China—in just four years—to launch its own space station, land on Mars, create its own satellite GPS system, and partner with Russia to territorialize the moon as well.[22] These were acts that rivaled the United States.

Historical Narrative

1950s: Qian Xuesen and Mao's Giant Space Leap for China

The official Chinese space program first began in 1956 under the People's Republic of China.[23] This brought an era of Chinese rockets, missiles, and satellites, which would soon

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[15] Chandrashekar, *China's Space Programme*; Harvey, *China in Space*.

[16] Brian Harvey, *China's Space Program: From Conception to Manned Spaceflight* (New York: Springer, 2004), 122.

[17] Harvey, *China's Space Program*, 125.

[18] Department of Defense and Full-Year Continuing Appropriations Act of 2011, Pub. L. No. 112–10, 125 Stat. 58 (2011), §§ 1340a–b.

[19] Harvey, *China's Space Program*, 191.

[20] NASA, "Artemis," 2020, www.nasa.gov/specials/artemis/. Bilateral agreement: NASA, "The Artemis Accords," 2020, www.nasa.gov/specials/artemis-accords/index.html.

[21] United Nations Office for Outer Space Affairs, "United Nations Office for Outer Space Affairs and NASA Sign Landmark Memorandum of Understanding to Advance Peaceful Uses of Outer Space," December 17, 2020, www.unoosa.org/oosa/en/informationfor/media/unoosa-and-nasa-sign-landmark-mou-to-advance-peaceful-uses-of-outer-space.html.

[22] "International Lunar Research Station (ILRS)," China National Space Administration, June 2021.

[23] Chandrashekar, *China's Space Programme*, 27.

be placed under the protection of China's military for safekeeping during the coming political upheavals.[24] During this time, a defining moment was brought on by American McCarthyism. In the words of biographer Iris Chang, it is "[t]he story of Tsien Hsue-shen, the brilliant, enigmatic, Chinese-born scientist who helped pioneer the American space age, [and] when rejected by the nation he sought to adopt as his own, became the undisputed father of the Chinese missile program."[25] Tsien Hsue-shen (Qian Xuesen) left China for America in his twenties. In the 1940s, he rose to American aerospace prominence for his mathematical abilities, MIT education, and Caltech collaborations. Qian was key in building America's rocket program, and he directed research at the Jet Propulsion Laboratory after working on the Manhattan project as a US Air Force colonel during World War II.[26] However, in 1949, when Mao Zedong took power in China, US "witch-hunters" accused Chinese-born Qian of communist sympathy and had him imprisoned.[27] After five years of house arrest, China traded American prisoners for Qian, and he returned to his birth country in 1955. Soon after, Mao made Qian—the Chinese scientist who had initiated America's space program—head of China's space program. Qian, whose name in Chinese means "knowledge like the forest," taught China's next generation of aerospace engineers.[28] By abusing democracy and human dignity, America had gifted China a scorned genius space scientist and military colonel. This emboldened China.

1960s–1980s: A Security Dilemma Unfolds

Around this time, a second defining moment spurred China's space program. It began in 1957 when the Soviet Union secretly launched the world's first artificial satellite and startled America into a security dilemma. Now the Soviets had advanced technology that could be used for military purposes. Immediately the US government established the National Aeronautics and Space Administration (NASA), and the 1957–1975 space race between the Soviet Union and the United States began. China, ever-cognizant of American abuse, became greatly threatened as America grew in space military power, and in 1958, Mao declared that space would be a national priority—an integral part of his Great Leap Forward. While the United States and the Soviet Union rivaled to send humans to space in the 1960s, China sent animals.[29] The program garnered public pride by naming its first satellite: "the East is Red," and its first launcher: "Long March," two terms that represented the heart of communist China. Under Qian, China advanced in Earth observation, weather monitoring, communications, space environment, aerodynamics,

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[24] Chandrashekar, *China's Space Programme*, 27, 39–40.
[25] Iris Chang, *Thread of the Silkworm* (New York: Basic Books, 1995).
[26] Gregory Kulacki, "Qian Xuesen," *Encyclopedia Britannica*, December 7, 2021, http://www.britannica.com/biography/Qian-Xuesen.
[27] Chang, *Thread of the Silkworm.*
[28] Chang, *Thread of the Silkworm.*
[29] Harvey, *China's Space Program*, 44.

orbital mechanics, rocket engines, and space medicine, and by 1970, China had formalized its human space program.[30] Despite the failures of Mao's Great Leap Forward and Cultural Revolution, Chinese space power advanced nearly in line with its international counterparts.[31] After Mao gave the program his approval in 1956, China was always a quiet contender for space power.[32]

Meanwhile, America had surpassed the Soviets in the race for space and succeeded in landing multiple human missions on the moon.[33] However, as the Cold War ensued, China continued to see the United States as a threatening military force. In 1971, Chinese Prime Minister Zhou Enlai met with US State Department delegate Henry Kissinger in Beijing. In this meeting, Zhou admitted to Kissinger that China felt unsafe. He said:

> Some people have asked us, since we advocate the complete prohibition and thorough destruction of nuclear weapons, why we are testing nuclear weapons. We must say very frankly that we do so to break the nuclear monopoly and to fight against the nuclear blackmail of certain great powers.[34]

This second defining era in China's space program derived from China's need to protect itself from American power.

1990s: From Limited Licensing to Blatant Exclusion of Chinese Space Collaboration

The Red Scare of the 1950s was not the only time America would fail in its space diplomacy with China. By the 1980s, the United States had begun to deny Chinese commercial satellite licenses. America had a long-standing claim that the Chinese space program was advancing through espionage and foreign bartering.[35] In 1996, when a Chinese launch carrying private American cargo failed, the United States accused China of stealing American satellite data chips from the wreckage. This resulted in another inquisition into Chinese collaboration in which a 1998 congressional committee accused China of using:

> over decades and in a systemic way, fair means and foul, neutral scientific conferences, licensing arrangements, dual-use military–civilian technologies

[30] Chandrashekar, *China's Space Programme*, 31.
[31] Chandrashekar, *China's Space Programme*.
[32] Chandrashekar, *China's Space Programme*; Harvey, *China's Space Program*; Harvey, *China in Space*.
[33] NASA, "The Apollo Missions," 2019, www.nasa.gov/mission_pages/apollo/missions/index.html.
[34] US Department of State, "Memorandum of Conversation," Washington, DC, Office of the Historian, July 10, 1971. history.state.gov/historicaldocuments/frus1969-76v17/d140.
[35] Oberg, "Testimony."

> and straightforward spying to ferret out information on nuclear technology, computers, rockets, submarines, and atomic bombs for decades.[36]

By now, the United States fully distrusted China and took China's every space move as militarily motivated. America put its International Space Station in orbit and did not allow China to participate. This excluded China from collaborating on the ISS with Russia, Japan, Canada, the United Kingdom, and the European countries cataloged under the European Space Agency. It was the third defining moment in China's space program rivalry with America; the United States had made China an outlier, preventing it from advancing in space technology as other nations advanced with the United States.

2000s: The Breaking Point That Propelled China to Rival American Space Power

The fourth defining moment in Sino–American space relations came in 2011, when the US Congress codified distrust of China by passing the Wolf Amendment.[37] Designed to prevent espionage, the law banned China from space collaboration with NASA. This forced American and global space companies to pick a side, with many of them opting for Chinese partnerships that offered lower prices in an international market.[38] America's marginalization of China caused other countries and private industry to choose between the dominating United States and an incentivized China, and China began to win.

In 2017, space relations between the United States and China reached a breaking point. In this fifth defining moment in the Sino–American space rivalry, NASA announced an American-led international accord to territorialize the moon—which excluded China. The People's Republic of China called this American act an "enclosure movement"; a confiscation of global commons.[39] In addition, the US plan threatened to funnel access between the Earth and moon by claiming crucial points in cislunar orbit.[40] Although the United States was corralling other countries to support the mission, it was a breach of international law—the 1967 Outer Space Treaty required equal space access for all and it prohibited lunar land claims.[41] After this, China propelled to outer space. By the time the United States realized that it had spurred a legitimate space rivalry with China, China was an equal in space technology.[42] By 2022, China had launched its own space station,

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[36] Harvey, *China's Space Program*, 125–27.

[37] Department of Defense and Full-Year Continuing Appropriations Act of 2011.

[38] Harvey, *China's Space Program*, 191.

[39] Stephen Chen, "China Speeds Up Moon Base Plan in Space Race Against the U.S.," *South China Morning Post*, December 29, 2021, www.scmp.com/news/china/science/article/3161324/china-speeds-moon-base-plan-space-race-against-us.

[40] NBC News, "Battlefield Space," *NBC News NOW Special,* May 26, 2022, youtu.be/IuiF6U-TFvQ.

[41] Treaty on the Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (OST), 1967, United Nations Office for Disarmament Affairs, treaties.unoda.org/t/outer_space.

[42] Mike Pence, Speech: "Make No Mistake About It—We're In a Space Race Today, Just As We Were in the 1960s, and The Stakes are Even Higher," National Space Council (NSC), 2019.

partnered with Russia on a moon base, created its own global GPS and satellite systems, and landed on Mars. And China—an active member in the United Nations' standards for equal access to space—invited the whole world to participate. China had met or exceeded American space power and space diplomacy and America was left with the consequences of having treated China as immoral, incapable, and substandard.

How and Why the Rivalry Happened

It is for these five defining moments in Sino–American space history that China grew to face the United States. The historical backdrop of unfair treaties, exclusionary laws, widespread American discrimination towards the Chinese since the mid-1800s, and the United States coercing China to adopt Western values of morality and democracy brought China to desire equality. When America failed in its mission to force China into democracy and partitioned from China in 1949, the Red Scare persecutions did not strengthen America's national security. Instead, they emboldened China with a new wave of purged scientists and the determination to succeed regardless of American scorn. However, between the 1950s and 1990s, America—the self-declared enemy of China—grew in military space technology. This greatly threatened China, as it saw it could not compete for national security unless it also developed advanced space weapons. When America excluded China from valuable collaboration with the United States and other spacefaring nations, this spurred China's need for international diplomacy and for support from the United Nations. After American anti-Chinese treatment stemmed from the 1996 rocket crash, the 1998 Cox report, the 1999 space station ban, and the full ban from the 2011 Wolf Amendment, China began to win America's market share in global space industry sales. Thus, China grew stronger while America weakened.

After NASA announced its exclusionary Artemis program, China moved to rival America in space power. Because NASA's act would block Chinese access to the moon and prevent China from building a lunar launchpad necessary for deep space travel, this was the breaking point for diplomatic relations between the United States and China, and it set the table for a militarized lunar arena. After China published its plan for an international moon base partnership with Russia and invited "all willing countries" to participate, the United States accused China of "trying to steal the moon."[43] Space diplomacy between China and the United States had reached its threshold as the US Air Force initiated a new team: the United States Space Force. The United States was ready to militarize space and stop China.

What the Rivalry Means

The United States created a security dilemma by growing in space military technology while simultaneously stifling China in space advancement. America made China feel

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[43] Reuters, "China Rejects Nasa Accusation It Will Take Over The Moon." *NBC News,* July 5, 2022, www.nbcnews.com/science/space/china-rejects-nasa-accusation-will-take-moon-rcna36656.

emboldened, threatened, excluded, and blocked. Because of this, China did not stop until it matched or exceeded the United States in space diplomacy, industry sales, satellite weapons and technology, human spaceflight, space travel, and space military power. In 2022, US and Chinese officials admitted that the two countries were in a dangerous race to territorialize the moon. The United States, however, refused to admit that China deserved to be a space equal. The US Congress also stated that China partnered with Russia to weaponize space, and that the US military must rise to meet the threat of Chinese space domination.[44] As a result, China must stand down or prepare to militarize against the United States. This kind of spiraling security dilemma has historically ended in a Thucydidean war, as when ancient Athens built a navy that exceeded neighboring Sparta's army, so Sparta attacked Athens to avert a future Athenian attack.[45] The space rivalry means that lunar access may be decided with military power—the United States and its allies fighting against China and its allies.

Conclusion

Although American policymakers argue that China cannot be trusted, this article argues that it is America's treatment of China that has made China harder to trust and that has turned China into America's greatest space rival. Every American exclusionary act made China stronger because China sought equality and safety. Perhaps ancient wisdom, which teaches that "unjust peace is far better than righteous war," gives insight to the issue.[46] Over the years, the United States has fundamentally disagreed with Chinese norms. However, excluding China from space collaboration did not make America stronger. Instead, it led to tensions teetering on a righteous war that Americans and the Chinese may pay for with lives, infrastructure, and generational wealth. Had America depolarized international relations with China and sought diplomatic peace, even if it was "unjust," acknowledging that both sides were right, and giving in whenever possible, perhaps China would not have become a space rival to the United States.

In hindsight, America should not have theorized that China was an enemy subjugate. China was a country that was doing its best to live peacefully and to prosper. America should have apologized many decades ago for its mistreatment of China and the Chinese. The children's children of those who made these decisions, some of whom dream to become astronauts and space travelers themselves, will suffer the consequences of America's strong resolve to avoid working things out.

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[44] Mike Rogers, "We Are Not Weaponizing Space. Space Has Already Been Weaponized By China and Russia. We Have to be Able to Defend Our Assets and We've Got to be More Aggressive In Doing So." R. Mike Rogers, Ranking Member, House Armed Services Committee, "Battlefield Space," NBC News NOW Special, May 26, 2022, youtu.be/IuiF6U-TFvQ.

[45] Thucydides *The History of the Peloponnesian War*, trans. Richard Crawley (Overlands, Park, KS: Digireads, 2017).

[46] Both Cicero and Erasmus made this observation.

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About the Author: Rebecca Schembri is an author and Space Diplomat from Reno, NV. She holds a bachelor's degree from Harvard University in Social Science and International Relations. She aspires one day to represent the United Nations as ambassador to the moon, Mars, or another celestial habitat. Follow: @rebeccafromreno.

Editors' Notes: Rebecca Schembri returns to the pages of the *JSP* for the third time in two years. As part of this retrospective issue, she turns the lenses of public policy and space diplomacy on the changing relationship between the United States and China as space superpowers. Like Grace Jones in the earlier article, Schembri reaches back to the 1950s to begin her narrative. She then illustrates how key milestones in the following decades led to a "dangerous race to territorialize the moon" in 2022. Her conclusions suggest that apologies may be key to a more unified approach in the decades ahead. ***Mark Wagner and Gordon Arthur.***

K12 Education for Space Settlement: An Ideas Unlimited Study

Mark Wagner, Brendan Brennan, Athena Brensberger, Joshua Dahn, Andrew Dobbie, Rosalyn Freeman, Janet Ivey, Bob Krone, Holly Melear, Rod Pyle, Steve Sherman, Rhonda Stevenson, Scott Thomas, Barbara Hopkinson Wagner, Artemis Westenberg, and Heather Wolpert-Gawron

Introduction

The purpose of this study is to explore how best to prepare current K12 students for humanity's multi-planet future. It begins with a review of literature in the field of space philosophy that demonstrates the benefits of space exploration, and thus the importance of educating students to be contributing participants in the coming settlement of the solar system and beyond. The study then includes the results of an original qualitative investigation of expert opinion using the Ideas Unlimited method and a grounded theory approach to generate actionable policy recommendations for educators and education leaders.

Literature Review

As Arthur has pointed out, the philosophy of space is a new and still developing discipline.[1] However, the space age is a historically significant period in human history that philosophers must confront.[2] Of primary importance to the practice of space philosophy is the question of why human beings should explore space, or whether we should. The purpose of this literature review is to answer that question based on a body of previous space philosophy, and to also consider the question through the lens of education; asking whether children should be educated for space exploration. In addition, some results of the review suggest how best to educate students for full participation in—and contribution to—the new space age of the next two decades, a time it seems will be characterized by an increase in activity from space agencies around the globe, expanding commercialization of space, and the return of crewed missions beyond low Earth orbit … to the Moon, Mars, and beyond.[3]

Benefits of Space Exploration

For a generation, children have been taught that the benefits of the space program include Tang, freeze-dried ice cream, and Velcro. While these products obviously fall far short of capturing the most important benefits, this sort of pragmatic justification is often

[1] Gordon Arthur, "Why Go to Space? The Academic Philosophy of Space Travel," *Journal of Space Philosophy* 10, no. 1 (2021): 54–68.

[2] Florence Hetzler, "Man and Space," *Dialectics and Humanism* no. 2 (1982): 51–64.

[3] Rod Pyle, *Space 2.0: How Private Spaceflight, a Resurgent NASA, and International Partners Are Creating a New Space Age* [Kindle Paperwhite version] (Dallas: BenBella Books, 2019). https://amazon.com.

the first response of space philosophers when asked why investment in space exploration is worthwhile. Spin-off technologies now found in daily life are often cited as clear benefits, including medical advances;[4] improved agricultural practices;[5] the ability to monitor the environment, weather, and pollution from space;[6] the Global Positioning System used for navigation;[7] and the increasingly space-based infrastructure of many government agencies and the public internet.[8] It is becoming difficult to imagine industries that are *not* likely to be affected by space technologies (particularly satellites) in the next two decades. In addition, government—and now commercial—spending on space exploration has another practical benefit: it drives both economic growth and scientific training in the workforce.[9]

Perhaps one of the biggest benefits of the space program so far is less tangible, but rather a change in the way the general population perceives the planet Earth and the place of humanity in its biosphere. From Russia's first cosmonaut Yuri Gagarin, who wrote of the transformational beauty of the Earth and his desire to see it preserved, to Shuttle astronauts, like Saudi Arabian Prince Sultan bin Salman Al-Saud, those who have been to space have often reported a change in perspective that transcends national borders and ethnic divisions.[10] Dubbed the Overview Effect by White, this cognitive shift in awareness became available to a whole generation when the general populace first saw photographs and videos of the Earth from the moon, leading to an ongoing change in public opinion evident in the international environmental movements of today.[11]

This shift in consciousness is just one of the ways space exploration has already benefited efforts to protect humanity's threatened environment on Earth. Satellite data are already critical to monitoring and addressing climate change. In fact, it is a false dichotomy to think that we must choose between investing in space exploration and investing in the protection of the environment on Earth.[12] Munévar sees space exploration as a means to a cleaner future on Earth,[13] later arguing that resources from around the

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[4] Hetzler, "Man and Space"; Pyle, *Space 2.0*.
[5] Pyle, *Space 2.0*.
[6] Hetzler, "Man and Space"; Pyle, *Space 2.0*.
[7] Pyle, *Space 2.0*.
[8] Frank White, "The Overview Effect and the Future of Humans in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 38–40; Pyle, *Space 2.0*.
[9] Pyle, *Space 2.0*.
[10] Walter Peeters, "Space Science as a Cradle for Philosophers," *Astropolitics* 10 (2012): 27–38, doi.org/10.1080/14777622.2012.647393; Pyle, *Space 2.0*.
[11] White, *The Overview Effect*.
[12] Arthur, "Why Go to Space?"
[13] Gustavo Munévar, "A Philosopher Looks at Space Exploration," in *Evolution and The Naked Truth*, ed. Gustavo Munévar (Aldershot: Ashgate, 1998), 169–79.

solar system can be used to resupply the environment of "spaceship Earth."[14] Munévar also considered the development of such systems an obligation to the future.[15] Not surprisingly, K12 students have agreed, expressing both a desire to protect the Earth and a concern about the future of the planet.[16] Protecting and even extending Earth's biosphere into space is likely to be a priority among space explorers. Kirby and Kiker recognized the importance of plants in any long-term space-based human habitat,[17] and Sobodowski predicted that spacefaring humans will create entirely new habitats that may be even more important than the Earth for the ultimate development of life in the solar system.[18]

If the environment is an urgent concern of our time, so is the need for greater diversity, equity, and inclusion on Earth—and here again space exploration may be beneficial. Among his reasons why the United States should return to the moon, Rogers listed "the benefit of all mankind"[19] and called for representation of all the Earth's 200 countries. In part due to the Overview Effect, involvement with space exploration encourages acceptance and inclusion of people from a diversity of backgrounds,[20] and as Krone pointed out, space is something of a cultural blank slate, defined by six decades of international collaboration, and no open war or conflict yet.[21] We still have an opportunity to expand into the rest of the solar system in a historically peaceful and inclusive way.

Munévar made a unique argument for the exploration of space on account of the unintended benefits of scientific serendipity.[22] For instance, nobody working on the Sputnik satellite could have predicted the daily use of Google Maps to navigate with a smartphone, which relies on GPS satellites; instead, our modern society has serendipitously benefited from the development of satellites. Arthur reasonably pointed out that there is no necessity involved in this argument; although serendipitous benefits

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[14] Gustavo Munévar, "Space Colonies and Their Critics," in *The Ethics of Space Exploration*, ed. James S. J. Schwartz and Tony Milligan (Cham, Switzerland: Springer International, 2016), 34.

[15] Gustavo Munévar, "Space Exploration and Human Survival," *Space Policy* 30 (2014): 199.

[16] Lonnie J. Schorer, "Children's Visions of Our Future in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 127–34.

[17] Richard Kirby and Ed Kiker, "Planning the Oasis in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 251.

[18] Joe Sobodowski, "Space Education, Learning, and Leading," *Journal of Space Philosophy* 2, no. 1 (2013): 15–18.

[19] Thomas F. Rogers, "Creating the First City on the Moon," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 57.

[20] Madhu Thangavelu, "Human Space Activity: The Spiritual Imperative," *Journal of Space Philosophy* 3, no. 1 (2014): 110–15.

[21] Robert M. Krone, "Philosophy for Humans in Space," *Journal of Space Philosophy* 2, no. 2 (2013): 78–82.

[22] Munévar, "A Philosopher Looks at Space Exploration."

may arise, and often do, there is no guarantee that they will … and sometimes science is instead quite dangerous or destructive.[23] However, unintended benefits of scientific inquiry have been a significant driver in human history, and there is no reason to believe that this trend will not continue into the future.[24] Presently, we are experiencing an acceleration in the development of new space technologies and the commercialization of the benefits—often at a rate even faster than anticipated.[25] Consider the rapid implementation of StarLink satellites, for instance, or the timeline for landing on the Moon and Mars set by SpaceX, which is far more aggressive even than the NASA missions they have been hired to deliver. It is reasonable to expect that serendipitous benefits may also come more quickly to the general populace.

Perhaps the most meaningful of the reasons traditionally given in support of space exploration might be the inspiration it offers to people around the world. Investment in the Apollo program drove not just the development of the modern space program, but also the rise of Silicon Valley and innovations in many other fields.[26] There is even an element of spiritual inspiration, as can be evidenced in the religious testimonies of astronauts and others influenced by the Overview Effect who have never even been to space.[27]

Critiques and Counter Arguments

Despite these many benefits of investing in space exploration, there are of course common critiques and counterarguments. As Arthur pointed out, social critics argue that resources would be better spent addressing more important problems here on Earth, and ideological critics argue that continued space exploration may be dangerous or even immoral.[28] Both critiques are now easily answered by space philosophers.

If a critic of the space program is concerned about care for the environment of the Earth, it has already been demonstrated that an investment in space has clear benefits for climate science and increasingly efficient agriculture. In addition, Munévar showed that humans are not alone as a species that transforms the environment, and that the ethical requirement is now for us to do so with wisdom … which information from space can aid us to do.[29] Furthermore, he argued that many disruptions to the balanced ecosystems of the past then led to greater opportunities for new life forms. He suggested that humanity (and all land animals) are the beneficiaries of environmental changes that led to life venturing from the sea onto land—and he suggested that humanity taking life into space

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[23] Arthur, "Why Go to Space?" This comment drew on Munévar, "A Philosopher Looks at Space Exploration."
[24] Krone, "Philosophy for Humans in Space"; Ord, *The Precipice*.
[25] Pyle, *Space 2.0*.
[26] Pyle, *Space 2.0*.
[27] Peeters, "Space Science as a Cradle for Philosophers"; White, *The Overview Effect*.
[28] Arthur, "Why Go to Space?"
[29] Munévar, "Space Colonies and Their Critics."

may have similarly long-term benefits for a variety of life forms. White would agree that we are the beneficiaries of the "explorer fish," and that we may play a similar role for future life forms.[30]

Similarly, Munévar recognized that we need to address problems on Earth by developing a better attitude toward equity and maturing beyond our historically colonial ethic of resource exploitation.[31] But not only can these changes be undertaken *in conjunction* with space exploration (there is nothing mutually exclusive about the two endeavors), but also they may actually be *enhanced* by the opportunity actually to put into practice something different as we expand into space. Humanity can explore the solar ecosystem through collaborating internationally, selecting more diverse crews, and focusing on making sure the benefits are realized by a more inclusive population … and the clean slate in space may be our best opportunity to do this.

The cost of space exploration is also a frequent concern of critics, particularly given the perception that these investments take away from investment in solving other problems. While it is clear that the Space Shuttle program was far too expensive, this concern is mitigated by the significantly reduced cost of newer spacecraft.[32] The rapid development cycles of SpaceX, for instance, are focused on minimizing costs, and they can deliver payloads and passengers to space for a fraction of the cost of past efforts or current competitors. Also, Pyle pointed out that most Americans actually have no idea what NASA's costs are, that its federal budget is currently about 90 percent lower than it was in the Apollo era, or that NASA is doing far more with comparatively fewer resources today.[33]

Whatever the costs, the dangers of space exploration are also commonly cited as reasons for avoiding investing in it, especially for crewed missions or human settlements. Even space philosophers agree that the integrity of a space station is fragile and that living in a space habitation would be considerably more dangerous than inhabiting an aircraft carrier.[34] Pyle captured this humorously in his anthropomorphized phrase, "space hates people."[35] Even K12 students understand the dangers, expressing a variety of fears about space exploration, especially in the wake of the *Challenger* and *Columbia* tragedies; however, many students still recognize that space settlement is risky but necessary.[36] Ord also acknowledged that humanity must not let the impossibility of knowing future dangers stand in the way of space exploration and the potential benefits,[37] and White

[30] White, *The Overview Effect*.
[31] Munévar, "Space Colonies and Their Critics."
[32] Arthur, "Why Go to Space?"
[33] Pyle, *Space 2.0*.
[34] Kirby and Kiker, "Planning the Oasis in Space."
[35] Pyle, *Space 2.0*, 15.
[36] Schorer, "Children's Visions of Our Future in Space."
[37] Ord, *The Precipice*.

went so far as to question whether humanity could continue to evolve and improve if it remains supposedly safe on Earth alone.[38] This brings us to the most important reasons for pursuing the exploration of space.

Critical Reasons for Space Exploration

Even recognizing the validity of these critiques, the most important reasons for space exploration are considerably more compelling. Nothing less than the survival of the human race, our greatest aspirations, and future stages of our evolution are at stake.

According to Krone,[39] space exploration is critical to the survival of humanity as a species, and he is far from alone in this belief. Munévar also advocated for colonization of other planets (and the galaxy) to ensure human survival in the long run.[40] This is articulated most completely in Ord's *The Precipice*, in which he demonstrates that a human expansion to other planets would protect the species against many natural catastrophes (including asteroid strikes, for instance) and against many human-made existential threats as well. Even politicians and diplomats recognized the threat in 1997 with the UNESCO *Declaration on the Responsibilities of the Present Generations Towards Future Generations*, which recognized that human survival may be at risk, and that acting on this knowledge falls within the mission of the United Nations.[41] More recently, Downing noted that strong global leadership is needed to avoid the probability of extinction.[42] Arthur brought home the importance of this reason when he cited Munévar's statement that "survival is of value to us because without it, our other aspirations are moot."[43]

It is our greatest aspirations that may be our most compelling reason for committing to space exploration. As explorers, we tap into our higher human nature to push boundaries and overcome obstacles.[44] And the coming decades will mean not just *explorers* in space, but the *pioneers* who will follow and create civilization there.[45] There may even be a positive feedback loop as we expand; ideally, we should be able to use space exploration (such as settlement of the Moon) to improve our culture,[46] our quality

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[38] White, *The Overview Effect*.
[39] Robert M. Krone, "Philosophy for Space: Learning from the Past—Visions for the Future," *Journal of Space Philosophy* 1, no. 1 (2012): 17–26.
[40] Gustavo Munévar, "Humankind in Outer Space," *International Journal of Technology, Knowledge, & Society* 4, no. 5 (2008): 17–25.
[41] Ord, *The Precipice*.
[42] Lawrence G. Downing, "Ethics, Values, and Moral Leadership for Space Settlements," *Journal of Space Philosophy* 8, no. 2 (2019): 56–60.
[43] Gonzalo Munévar, "The Morality of Rational Ants," in *Evolution and the Naked Truth*, 131–47. Munévar draws on the work of Peter Singer, E. O. Wilson, and Charles Darwin. Quoted in Arthur, "Why Go to Space?" 61.
[44] Pyle, *Space 2.0*.
[45] White, *The Overview Effect*.
[46] Rogers, "Creating the First City on the Moon."

of life,[47] and the models available for those left on Earth to emulate,[48] thus ensuring benefits for future generations both on and off the Earth.[49] White considered planning for space exploration and settlement to be synonymous with planning the evolution of human civilization (and perhaps the evolution of the universe itself).[50] In this way, expanding human civilization beyond Earth helps us to preserve our potential, avoiding biological or cultural lock-in that might limit it forever.[51] If Earth is alone in supporting life, humanity might be its best or only chance not only to avoid eventual extinction, but also to expand and flourish.[52] After all, "the Earth is the cradle of mankind, but one cannot remain in the cradle forever."[53]

It is the future of life beyond the human that perhaps *should* be our highest concern. Many space philosophers are already considering a post-human (or posthumanist) future where the biological or inorganic descendants of humanity, such as designer life forms or artificial intelligences, are better suited to flourishing beyond the cradle of Earth. This is why White suggested not just a human space program, but a post-human space program broad enough to include humans, non-humans, post-humans, extraterrestrials, and any non-organic intelligence; and he imagined post-humans swimming through space like dolphins, a hypothetical species he dubbed *Homo spaciens*.[54] Similarly, Todd wondered what type of posthuman we will decide to become,[55] and Ord argued for a future in which people explore a diverse variety of post-human forms.[56] White also noted that humans may not need to understand their role in the evolution of intelligence in the universe to fulfill it, and he postulated that the purpose of human evolution may be to make a contribution to the universe rather than exploit it.[57] Realization of such a future will require

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[47] Kenneth J. Cox, Robert M. Krone, and Langdon Morris, "Theory and Action for the Future of Humans in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 271–75.
[48] K. T. Connor, Lawrence G. Downing, and Robert M. Krone, "A Code of Ethics for Humans in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 119–26.
[49] Pyle, *Space 2.0*.
[50] White, *The Overview Effect*.
[51] Ord, *The Precipice*.
[52] Ord, *The Precipice*.
[53] Tsiolkovsky, quoted in Peeters, "Space Science as a Cradle for Philosophers," 79.
[54] White, *The Overview Effect*.
[55] Joseph Todd, "A Utopian Mirror: Reflections from the Future of Childhood and Education in Aldous Huxley's *Brave New World* and *Island*," in *Childhood, Science Fiction, and Pedagogy: Children Ex Machina*, ed. David W. Kupferman and Andrew Gibbons (Singapore: Springer Nature, 2019), 135–54.
[56] Ord, *The Precipice*.
[57] White, *The Overview Effect*.

new global systems of governance,[58] greater participation of the general populace, and ultimately the transition of space exploration efforts from a government project to a civilization-wide undertaking.[59] Preparing a new generation of students for this impending transition is very much the mandate of existing school systems, though they may not be well prepared for the challenge.

Should Children be Educated for Space Exploration?

Given these compelling reasons for humanity to invest in space exploration, it follows that it may be wise to prepare children to participate in and contribute to the coming new Space Age. It may even be something of a moral imperative to provide them this preparation for the world they will likely live in … and help to shape. As White suggested, we can now make preparations such as this with clear intention.[60] If we must explore space to promote peace, as Cox suggested, then perhaps schools should be a part of that learning process as early as possible.[61] And if Dror advocated for a Global Leadership Academy, then perhaps that learning should start as early as possible too—and for a much wider set of students—so that they can then be well prepared for the sorts of careers and leadership roles Dror advocates in his steps for redesigning global society.[62] These can include Dror's new space settlement profession, Peeters's space ronin—the independent rogues who serve as change agents,[63] and Arthur's wide range of disciplines involved in space settlement.[64] Here again, K12 students would agree … they expect our species to advance through study and exploration.[65]

So, if schools should be redesigned so that they better prepare students for humanity's multi-planet future, what should be the foundational principles of those schools? Though an additional answer to this question is offered in the study results below, the literature of space philosophy does provide some initial guidance. It is clear that the school should be hands on,[66] following constructivist learning principles and focusing on empowering

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58 Yehezkel Dror, "Governance for a Human Future in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 41–45.

59 Cox et al., "Theory and Action."

60 White, *The Overview Effect*.

61 Cox et al., "Theory and Action."

62 Dror, "Governance for a Human Future in Space."

63 Peeters, "Space Science as a Cradle for Philosophers."

64 Arthur, "Why Go to Space?"

65 Schorer, "Children's Visions of Our Future in Space."

66 Becky Cross, "Sowing Inspiration for Generations of Space Adventurers," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 135–37.

the learner.[67] Students should also be trained in the practice of philosophy themselves, from classical philosophy including stoicism,[68] to the philosophy of science.[69]

In a sense, science fiction is "philosophy of the future," and it should be explicitly included in the learning experiences of the new schools; Hetzler called for philosophers (and by extension educators) to be open to thinking about possible worlds,[70] and Krone considered science fiction a staple of literature.[71] Perhaps more importantly, Levinson and Jandrić recognized the role science fiction has played in driving scientific innovation forward,[72] and it follows that if inspiring more scientists is an important goal, then science fiction should be a focus in schools. Similarly, if educating more creative problem-solvers is important, then exposing students to science fiction may be helpful, as the genre encourages imagination, speculation, and … delight.[73] Kupferman and Gibbons also pointed out that "science fiction reveals to the child the nature of the system in which s/he is being educated" and introduces children to "different forms of educational future."[74]

Engaging students in this sort of reflection will also be critical in a school designed to prepare students for altruistic space exploration—and to avoid potentially dystopian alternative futures.[75] Ultimately, reflection is also a necessary ingredient of the sort of wisdom that will be required of future leaders and citizens as humanity expands into space; the need for wisdom is a common thread through much of space philosophy, particularly with respect to global leadership, policy, and governance.[76]

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[67] Phillip W. Simpson and Andrew Gibbons, "Filling the Mind: Cortical Knowledge Uploads, Didactic Downloads and the Problem of Learning in the Future," in *Childhood, Science Fiction, and Pedagogy: Children Ex Machina*, ed. David W. Kupferman and Andrew Gibbons (Singapore: Springer Nature, 2019), 155–69.

[68] Dror, "Governance for a Human Future in Space."

[69] Peeters, "Space Science as a Cradle for Philosophers."

[70] Hetzler, "Man and Space."

[71] Robert M. Krone, "Music and Arts for Humans in Space," in *Beyond Earth: The Future of Humans in Space*, ed. Bob Krone, Edgar Mitchell, Langdon Morris, and Kenneth Cox (Burlington, ON: Apogee Books, 2006), 114–18.

[72] Paul Levinson and Petar Jandrić, "Children and Pedagogy between Science and Fiction," in *Childhood, Science Fiction, and Pedagogy: Children Ex Machina*, ed. David W. Kupferman and Andrew Gibbons (Singapore: Springer Nature, 2019), 211–26.

[73] Walter S. Gershon and Reagan P. Mitchell, "Your Android Ain't Funky (Or Robots Can't Find the Good Foot): Race, Power, and Children in Otherworldly Imaginations," in *Childhood, Science Fiction, and Pedagogy: Children Ex Machina*, ed. David W. Kupferman and Andrew Gibbons (Singapore: Springer Nature, 2019), 93–110.

[74] David W. Kupferman and Andrew Gibbons, "Why Childhood Ex Machina?" in *Childhood, Science Fiction, and Pedagogy: Children Ex Machina*, ed. David W. Kupferman and Andrew Gibbons (Singapore: Springer Nature, 2019), 10.

[75] Todd, "A Utopian Mirror."

[76] Dror, "Governance for a Human Future in Space"; Robert M. Krone, "Utopia: Space Philosophy and Reality," *Journal of Space Philosophy* 2, no. 2 (2013): 44–48; Munévar, "Space Exploration and Human Survival"; Ord, *The Precipice*.

Summary of the Literature Review

It is clear that the benefits of space exploration are many, and that humanity cannot take advantage of them without proper planning and collaboration on a global scale. Spinoff technologies and serendipitous scientific discoveries that benefit the general populace are only the beginning. More significant benefits include the perspective-shifting Overview Effect; the technology to monitor and deal with climate change; the opportunity to practice diversity, equity, and inclusion on a global (and interplanetary) scale; and the inspiration of new generations of scientists, explorers, and pioneers. As the costs of space exploration come down and the understanding of the dangers improves, some critical benefits clearly outweigh the risks. Space exploration may help humanity to avoid existential threats, making it possible to achieve our highest aspirations as a species—and to move ethically into a post-human future of essentially unlimited potential.

Therefore, it is clear that it would be best to prepare the world's youth for this future in space, and that schools should be redesigned for this function. These new schools should provide opportunities for active learning while building students' foundations in philosophy, science fiction, and effective reflection so that they might one day serve as wise leaders and citizens.

Method

This qualitative study followed a grounded theory approach using the Ideas Unlimited method to engage a panel of experts and make their tacit knowledge explicit for real-world implementation, and for further research. The researcher operated from a social constructivist paradigm, a common foundation for education research resting on the belief that the human mind is constantly engaged in developing subjective meanings from the environment in which it lives, and that meaning making is a process of social negotiation via dialogs or conversations between individuals.[77]

School design is a complex long-term undertaking faced with many human elements that limit the effectiveness of quantitative analysis, making a qualitative approach more appropriate, especially with an emerging future context such as space settlement. Trochim defined qualitative research as a process involving any measures where the data are not recorded in numerical form, and he included short written responses on surveys among his examples of qualitative data.[78] These measures are especially appropriate in a social constructivist context because qualitative researchers are interested in the meaning that

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[77] John W. Creswell, *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*, 2nd ed. (Thousand Oaks, CA: Sage, 2003); David H. Jonassen et al., *Learning to Solve Problems with Technology: A Constructivist Perspective* (Upper Saddle River, NJ: Merrill Prentice Hall, 2003).

[78] William M. K. Trochim, *The Research Methods Knowledge Database*, 2nd ed. (Cincinnati: Atomic Dog, 2001).

people construct and how they make sense of the world and their experiences in it.[79] The role of the researcher in qualitative research is thus to gather, analyze, and interpret data—a process that requires careful observation, tolerance for ambiguity, confidence in intuition, and clarity in communication.[80]

Because we do not know of any K12 schools that focus on preparing students for humanity's multi-planet future, a grounded theory approach is an effective choice for generating new ideas. According to Leedy and Ormrod, "the major purpose of a grounded theory approach is to begin with the data and use them to develop a theory."[81] In this case, the study works from the expert opinions of the participants to derive an abstract theory to guide policymakers.[82]

In particular, the Ideas Unlimited method is well proven for planning purposes, improving performance, and generating new ideas. According to Downing et al., "Ideas Unlimited collects and organizes ideas from people to solve strategy, policy, planning, program, process, task, or procedural problems."[83] Traditionally, ideas are collected on small slips of paper, thus the original name of C. C. Crawford's "Crawford Slip Method" before Bob Krone coined the name "Ideas Unlimited."[84] For this 2020 study, an online *Google Form* was used to collect submissions asynchronously from geographically dispersed participants into a collaborative web-based *Google Spreadsheet* shared between the researcher and his academic advisors. Participants responded to a single prompt, known as a "target" in the Ideas Unlimited method that was designed to focus their mind on their relevant experience.[85] Their responses were then copied from the spreadsheet into the *Zotero* qualitative research software for a process of tagging, keyword classification, and data reduction, with a focus on making recommendations for performance improvements.[86] An outline of the results was created using the online outliner *Workflowy*, and this analysis is the final outcome of the study. The researcher was personally responsible for all aspects of implementing the Ideas Unlimited process. He composed the target (and associated instructions, though these were adapted from a target sheet created by Bob Krone at Kepler Space Institute), recruited all participants, analyzed all data, and interpreted all findings.

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[79] Sharan B. Merriam, *Qualitative Research and Case Study Applications in Education* (San Francisco: Jossey-Bass, 1998).

[80] Creswell, *Research Design*; Merriam, *Qualitative Research*.

[81] Paul D. Leedy and Jeanne E. Ormrod, *Practical Research: Planning and Design*, 8th ed. (Upper Saddle River, NJ: Pearson, 2005), 140.

[82] Creswell, *Research Design*.

[83] Lawrence G. Downing, Robert M. Krone, and Ben A. Maguad, *Values Analysis for Moral Leadership* (London: Bookboon, 2016), 30. https://bookboon.com/premium/books/values-analysis-for-moral-leadership.

[84] Robert M. Krone and Selena Gregory-Krone, *Ideas Unlimited: Capturing Global Brainpower* (Wilmington, DE: Stratton Press, 2018).

[85] Krone and Gregory-Krone, *Ideas Unlimited*.

[86] Downing et al., *Values Analysis for Moral Leadership*.

Fifteen participants were included in the study, each an expert in space philosophy, education, or both. All participants are credited as co-authors of this paper. Their names, titles, and professional affiliations also appear in Appendix A. The following is the target to which each of them responded:

> Future space exploration and settlement: How might K12 schools best prepare students for success in humanity's multi-planet future?

Results

Several themes emerged from the analysis of participant responses to this target prompt. In general, there was consensus around what might be considered constructivist ideals: a focus on a learning experience that is engaging, context-embedded, inquiry-driven, collaborative, and supportive of metacognition. As such, mentorship (as opposed to teaching) was a focus of the responses, as was problem-solving (as opposed to rote learning and recall). Not surprisingly, the importance of technical skills came up often, but so did a variety of "softer" skills, including art, philosophy, and leadership. Finally, there was a consistency in participants' vision for a better future—a world inspired by utopian science fiction, characterized by equity, abundance, and humanist or post-humanist perspectives.

A constructivist learning environment can be said to be engaging, context-embedded, inquiry-driven, collaborative, and supportive of metacognition.[87] Participant responses tended to include many of these elements. For example, space educator Holly Melear argued that traditional approaches such as handouts, memorization, and testing would not be effective in preparing youth for success in off-world communities; instead, she advocated for students to be working in cross-curricular multi-age teams focused on solving real-world problems. Janet Ivey, host of *Janet's Planet*, suggested similarly authentic experiences, including activities such as planning Martian settlements, creating model robotic arms, or designing "astro socks" to protect astronauts' feet as they hook onto footholds in zero gravity. Rod Pyle, author of *Space 2.0,* also recommended *engaging* projects, field trips to space facilities, and connecting with scientists, engineers, and other space industry professionals. Additional participants suggested that students should complete *context-embedded* hands-on projects while learning about existing space policies, such as the Outer Space Treaty, and conducting interviews with professional astronauts. An *inquiry* process driven by student agency (including giving students "more practice in exercising power") was also a hallmark of many responses. A call for *collaborative* elements included cooperation, respect, and appreciation of unique contributions—and also included a more inclusive reduction in elitist attitudes. Rosalyn

[87] Mark D. Wagner, "Massively Multiplayer Online Role-Playing Games as Constructivist Learning Environments in K–12 Education: A Delphi Study" (PhD diss., Walden University, 2008), https://edtechlife.com/dissertation/.

Freeman, herself a student, also promoted the idea that students should rely on each other as they perform tasks similar to those of a multi-planet society. *Reflection and metacognition* appeared in several responses, with a focus on student analysis of learning outcomes, both in authentic research as a part of completing projects and in the context of more formal academic writing. In keeping with these constructivist methodologies, direct instruction was de-emphasized in favor of more meaningful mentorship from people who work in the space industry (such as experts at NASA, JPL, and elsewhere).

Realistic problem solving was a near universal recommendation of the participants. There were explicit calls for *project-based learning* (from Melear, Ivey, and others) including many suggestions of specific space-themed hands-on challenges. These projects were typically open ended with an expectation of multiple (and multi-disciplinary) paths to success. A *design thinking* approach was common, in which students would come to understand a problem (and the people it affects), ideate possible solutions, build prototypes, test their theories, and iterate on their creations to improve outcomes. For example, Assistant Principal Scott Thomas suggested teaching students engineering skills in the context of designing space habitats. Others embedded such challenges into a game or game-like format.

Activities involving technical skills were common recommendations, with a broad emphasis on science, technology, engineering, and math (*STEM*) skills, many of which were focused on the challenges of survival in outer space or in the hostile environments of other planets. Andrew Dobbie, a Grade 6 teacher, suggested that students be tasked with developing Arduino- or Raspberry Pi-controlled systems for meeting survival needs, such as lighting for plants, air filtration, or waste recycling. Other suggestions for STEM projects included environmental studies, resource stewardship, and challenges related to governance or interpersonal dynamics. Naturally, there were explicit calls for a wide range of *science education* as well, including other *coding* projects, such as games or *simulations*, and *maker* projects, such as 3D printing or model building from household materials (Ivey mentioned a papier mâché spacesuit helmet). Learning experiences were also expected to include cutting-edge technologies; some, including Freeman, wanted students to learn using augmented or virtual reality headsets and gloves.

Responses that focused on technical skills were balanced by similarly numerous discussions of softer skills, including art, creativity, social emotional learning, personal growth, philosophical thinking, spirituality, and leadership development. The importance of *art* was a common concern, with Melear stressing the critical role of the arts for design, beauty, and stress relief, and Ivey advocating a wide variety of projects, including songwriting, dances, and travel brochures or various visual media as mock marketing materials. Others focused on the *creativity* in students finding their own paths to success. There were also explicit calls for the development of interpersonal skills and *social–emotional learning* for personal growth … even approaches like practicing mental health, compassion (and self-compassion), social restoration, collaborative meditation, development of spiritual relationships, and intentional culture building. Some correlated this sort of personal growth to developing familiarity with classical *philosophy*—and with Stoic resilience in particular. Naturally, several participants also pointed out the importance of helping students to develop their *leadership skills*, which can be accomplished by allowing students opportunities to lead their peers while engaging in the sorts of projects and problem solving suggested above.

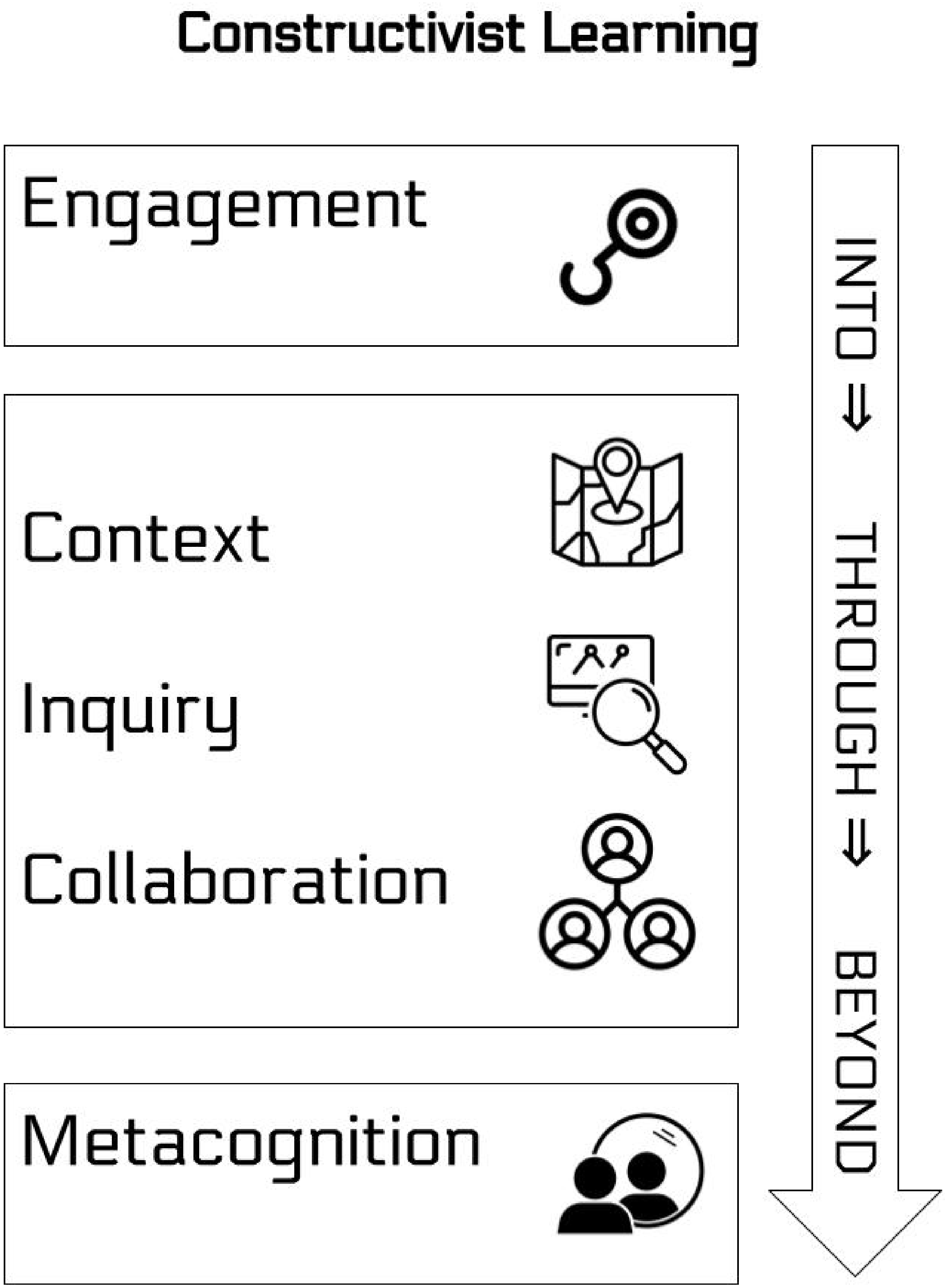
Participants tended to espouse an optimistic vision for the future, inspired in part by science fiction, but also their hopes for an inclusive global society with a sense of abundance for all, and with the commitment to duties, policies, and progressive administrations required to make that a reality. Some responses suggested establishing an environment of optimistic thinking for students, encouraging them to believe in themselves and pursue their dreams. Ivey included the practice of calling students by aspirational titles such as "Astronaut Aiden." These recommendations are explicitly meant to be inclusive and equitable for a diversity of students around the world, with an acknowledgment of the interpersonal, cultural, and ethical challenges involved in this "international investment." There were also concerns about overpopulation on Earth, but a generally optimistic belief in humanity's ability to settle other habitats throughout the solar system, and in the validity of both the Overview Effect and the Law of Space Abundance (which suggests that space has abundant resources to meet human needs). Respondents advocated helping students to develop a sense of duty and ownership over the solutions to such systemic problems. This included introducing students to issues of governance, including the policy sciences, and also working directly with current political administrations so that students can gain experience in dealing authentically with similar issues today. In keeping with these philosophies, several participants recommended that educators provide opportunities for students to study science fiction as inspiration; for example, Dahn expected instructors to select appropriate books and films for their students, and Pyle suggested a focus on the overlap between real science technology and science fiction. In addition, some explicitly recommended exposing students to the *Journal of Space Philosophy* published by Kepler Space Institute.

Conclusion

It is clear from the literature review that the benefits of space exploration are many, and that humanity cannot take advantage of them without proper planning and collaboration on a global scale. Spinoff technologies and serendipitous scientific discoveries that benefit the general populace are only the beginning. More significant benefits include the perspective-shifting Overview Effect; the technology to monitor and deal with climate change; the opportunity to practice diversity, equity, and inclusion on a global (and interplanetary) scale; and the inspiration of new generations of scientists, explorers, and pioneers. As the costs of space exploration come down and the understanding of the dangers improves, some critical benefits clearly outweigh the risks.

Space exploration may help humanity to avoid existential risks, making it possible to achieve our highest aspirations as a species—and to move ethically into a post-human future of essentially unlimited potential.

Given this evident moral mandate to prepare students for humanity's multi-planet future, the results of this new Ideas Unlimited study suggest a clear plan of action for educators and education policy makers. It is critical that a *constructivist* approach to active learning be adopted, with a focus on creating learning experiences that are engaging, context-embedded, inquiry driven, collaborative, and supportive of reflection and metacognition. Methods should focus on *mentorship* (as opposed to didactic teaching) and on authentic real-world *problem-solving* (as opposed to rote learning and recall). *Technical skills* should certainly be emphasised (including coding, making, and the practice of the scientific method), but so should a variety of *soft skills,* including creativity, social emotional learning, and leadership development. Finally, educators should uphold an optimistic worldview, inspired by the best of science fiction, and characterized by equity, abundance, and a post-humanist vision for humanity's future in the solar system and beyond.


Constructivist Learning
Engagement
Context
Inquiry
Collaboration
Metacognition
INTO ⇓ THROUGH ⇓ BEYOND

Appendix A: Participant Names, Titles, and Affiliations

Name	Title	Affiliation
Brendan Brennan	Co-Founder	ARES Learning
Joshua Dahn	Executive Director	Astra Nova School
Athena Brensberger	Science Communicator	Astroathens
Andrew Dobbie*	Grade 6 Teacher	SDG Global Ambassador
Rosalyn Freeman*	Student	MPH
Janet Ivey*	CEO	Janet's Planet, Inc.
Bob Krone	Former President	Kepler Space Institute
Holly Melear*	CEO & Founder	STEAMSPACE Education Outreach
Rod Pyle*	Writer and Editor	National Space Society
Steve Sherman	Chief Imagination Officer	Living Maths
Rhonda Stevenson	President/CEO	Tau Zero Foundation
Scott Thomas*	Assistant Principal	Stuyvesant High School
Barbara Hopkinson Wagner	Social Awareness Educator	Kids Are the Solution Project
Artemis Westenberg	CEO	Explore Mars Europe
Heather Wolpert-Gawron	21st Century Learning	San Gabriel Unified School District

* All participants in the study are credited as co-authors on this publication. Participants indicated with an asterisk requested credit in the body of the text for their specific contributions.

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About the Author: Mark Wagner serves as President of the Space Prize Foundation, a non-profit organization focused on promoting STEM education and increasing the representation of women in aerospace careers. He also teaches the Space Education graduate certificate program at Kepler Space Institute and is the Associate Editor of the *Journal of Space Philosophy*. In addition, he is the founder of ARES Learning, a vision for schools that prepare students with the skill sets and mindsets they will need to be successful in the growing space economy—and in humanity's rapidly approaching multi-planet future. Mark has a PhD in Educational Technology and a master's degree in Cross-Cultural Education. He also holds graduate certificates in Space Education and Space Philosophy. He is the author of *More Now: A Message from the Future for the Educators of Today* (2018) and a forthcoming book about space education, which explores both current opportunities on Earth, and the possibilities for teaching students on the Moon, on Mars, and in deep space habitats. Outside his work, Mark loves playing hockey, practicing martial arts, and obsessing over his '62 beetle, which now runs on an electric motor and Tesla batteries. He is a certified health coach and biohacking enthusiast, who also enjoys songwriting, spending time in nature, and exploring the world with his friends and family.

Editor's Notes: Contributing an article to the *JSP* for the fourth time, Dr. Mark Wagner (our associate editor) offers not only a look ahead at how we might prepare students for humanity's rapidly approaching multi-planet future, but also an academic justification of why that is important to everyone. Drawing on the space philosophy of the past decades, including several of the authors included in this issue, he argues that space education is a moral imperative and provides recommendations for how best to move forward. At this point of the issue, we have moved squarely into prospective material. ***Gordon Arthur.***

Space Marketing Trifecta Strategies: Corporate Responsibility, Climate Crisis, and the Space Industry

By Izzy House

Abstract

There are powerful marketing opportunities that combine the activities of the space industry with corporate responsibility that can mitigate the climate crisis. Companies that embrace this trifecta of strategies can develop a brand story that resonates with their audiences while benefiting the planet.

Keywords: Space marketing, corporate responsibility, climate crisis, climate change, space economy, space industry, marketing strategies, content development, business, sustainability.

Introduction

Historic flooding, freakish storms, wildfires, and heat waves that kill thousands—does this signal that climate change is turning into a climate crisis? The planet is changing, and it is finally getting the attention it needs. These events are stimulating conversations that need to happen, and the climate crisis is beginning to trend. Corporate responsibility and the space industry is also beginning to trend in popularity. Combining all three trends into a marketing strategy generates goodwill and trust, and it may help to save our world.

Marketing is usually seen as a type of sales tool that is interruptive and annoying while trying to take our money in exchange for a subpar product. Marketing is so much more than an annoying ad or commercial, and it can be a powerful tool that can have a positive impact. Marketing has the power to change the world. It can save lives and create positive movements. It can eradicate diseases like polio by initiating widespread vaccination, spread the call for freedom against tyranny, or galvanize a county to step on the Moon. Marketing also has the power to save our world from ourselves. As the concern and conversation grows about the health of our planet, it can be a useful strategy for business messaging to join the conversation and bring about real change.

What is Marketing?

The term *marketing* can be confusing even to those in the industry. The American Marketing Association's official definition is "Marketing is the activity, set of institutions, & processes for creating, communicating, delivering, & exchanging offerings that have value for customers, clients, partners, & society at large."[1] The basic translation for this definition means that it is everything that a company does to interact with its audience.

[1] American Marketing Association, "Definitions of Marketing," July 20, 2022, www.ama.org/the-definition-of-marketing-what-is-marketing/.

There are different facets of marketing. Sales is the human touch point of marketing. Public affairs is the news and crisis-handling facet of marketing. Advertising is paid promotion to bring awareness of a campaign or offer. These terms are not interchangeable with marketing, but they are part of it, just as the hand is not the body, but it is a valuable part of it. Marketing includes everything your brand does, including product creation, messaging, how your employees interact, and even what your storefront smells like (yes—that is a thing—scent marketing). Marketing also includes the science behind the scenes that determines who your audience is, how to craft strong messages that resonate with it, and how to measure the effectiveness of each interaction.

Marketing is more than just a vehicle to sell a widget. It is the bullhorn that brings awareness. Marketing is powerful, and it can create change. It has the power to bring an idea to the masses that can spur the adoption of electricity, eradicate disease like polio, liberate a country from an oppressive regime, and put a man on the Moon. Marketing is critical for any movement to happen. It brings the issue into awareness. This is true for the climate crisis, space exploration, and corporate responsibility. As these subjects begin to dominate the conversation, companies will be encouraged to take actions that make sure that they are a positive part of the discussion.

The Climate Crisis is Trending

People are talking about the climate crisis because there is real concern for the future of our planet. The public is noticing water levels rise, temperatures climbing, and evidence of pollution. It is difficult to ignore wildfires and floods, as they erase lives in an instant. It is becoming personal, and people are demanding action before it is too late.

Marketing can enhance social pressure to initiate positive change. During the 1970s and the 1980s, satellite technology discovered holes in the ozone that were caused by chemicals in aerosols. Concerned scientists used technologies to determine what was causing the holes. They used marketing to share their findings with the public to create change.

In 1985, social pressure saw complete international cooperation resulting in the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987.[2] Marketing tactics can help to build momentum by informing the public about the actions that need to happen to initiate change from new laws to pressure for more eco-driven goods and services.

Space is Trending

Satellites have been a part of our daily routine for decades. Weather forecasting, climate monitoring, and communications pour into our devices and reveal the damage

[2] Environmental Protection Agency, "International Treaties and Cooperation About the Protection of the Stratospheric Ozone Layer," www.epa.gov/ozone-layer-protection/international-treaties-and-cooperation-about-protection-stratospheric-ozone.

that humanity's industry and consumerism has done to the planet. The eyes of space have given scientist solutions and instigated valuable legislation that has resulted in tangible results. For example, the holes in the ozone layer were detected and measured using NOAA and NASA researchers' satellite instruments aboard Aura, Suomi–NPP and NOAA–20 satellites.[3]

Space provides a miniature ecosystem that allows scientists to study the effects of our activities and provides a platform to develop clean technologies. The International Space Station produces technology like filtration systems that can create clean water and air. There have been over 3,300 research projects in the past two decades on issues that impact our climate, from farming practices to manufacturing to solar technology.[4]

Corporate Responsibility is Trending

People want to do business with companies that give back and take responsibility. The tolerance for corporate fleecing of the public is over. It matters to customers that their chosen products do not harm the planet and that they are sustainable. A catchy jingle or tagline is not enough anymore. Corporations, organizations, and small businesses must step up. The people are demanding that those who have done the most damage with manufacturing and design clean up the mess they have left behind.

Satellites measure changes in our climate and pollutants in our environment. Valuable data can impact corporations and small business decisions about their environmental footprint. The conversation on sustainability and responsibility will happen. Business leaders will need to decide on which side of the conversation they will find themselves. They can control the message by implementing positive environmental changes within their business practices and reap the rewards of public support or ignore the signs and be deemed the villains.

Trifecta of Marketing Strategies

The pressure for change can provide new opportunities for marketing initiatives that are part of the conversation and that have positive results for our planet and survival. By displaying corporate responsibility through space activities that improve our home, some companies have embraced this trifecta of strategies and are using space to develop greener products. As these three trends merge, they produce powerful results. It is a win for the planet as big businesses change from harmful practices and start using sustainable business practices. It is a win for the citizens of our planet who get to live better and

[3] National Oceanic and Atmospheric Administration, "Antarctic Ozone Hole is 13th Largest on Record and Expected to Persist into November," www.noaa.gov/news/antarctic-ozone-hole-is-13th-largest-on-record-and-expected-to-persist-into-november.

[4] NASA, "Entering the Decade of Results: Benefits for Humanity Released," July 11, 2022. www.nasa.gov/mission_pages/station/research/news/benefits-2022-book.

healthier lives. It is a win for our humanity as we make positive change. It is a win for companies to have a brand story that people trust and support.

Estée Lauder is an exclusive partner of the ISS National Lab Sustainability Challenge, which is funding research for future-thinking plastics alternatives, The objective of the sustainability challenge is to use the unique ISS environment to develop, test, or mature products and processes that address at least one of three goals: reduce plastic waste introduction into the environment, seek alternative feedstocks and pathways for polymer production beyond petrochemicals, and reduce virgin plastic manufacturing. In addition, Estée Lauder is a founding member of the Sustainable Packaging Coalition.[5]

Target Corporation has also partnered with the ISS National Lab's ISS Cotton Sustainability Challenge. This challenge focuses on improving the use of natural resources such as water for sustainable cotton production on Earth. Two of the resulting studies seek to create water-saving strains of cotton and a third challenge recipient is focused on providing real-time information to farmers to manage water use and crop production better.[6] Target received an honorable mention along with some great earned-marketing exposure from the influential business magazine, Fast Company's 2019 World Changing Ideas Awards,[7] which "celebrate businesses, policies, and nonprofits that are poised to help shift society to a more sustainable and equitable future."[8] This event is another example of the power of this marketing strategy and how it is gaining momentum.

A third notable company that is building a brand story with this trifecta powerhouse strategy is Vaya Space. Vaya Space created rocket fuel from recycled plastic bottles making it the first green rocket. Each launch uses more than two million discarded water bottles. In addition, Vaya Space participates in the International Coastal Cleanup.[9]

All these companies earns media coverage as outlets talk about what they are doing in addition to the influential content they produce. This creates a feeling of goodwill and trust among their audience. It fosters hope that something can be done and that these companies are doing something about our home planet. It enforces the identity of their consumers who demand their products like Estée Lauder's customers, or those who shop at Target's stores.

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[5] Estée Lauder Companies, "Estée Lauder Joins the International Space Station National Lab's Sustainability Challenge as Exclusive Partner," www.elcompanies.com/en/news-and-media/newsroom/press-releases/2021/10-28-2021.

[6] ISS National Laboratory, "Target ISS Cotton Sustainability Challenge Receives Honorable Mention in Fast Company's World Changing Ideas," www.issnationallab.org/iss360/target-iss-cotton-sustainability-challenge-receives-honorable-mention-in-fast-companys-world-changing-ideas/.

[7] Morgan Clendaniel, "World Changing Ideas 2019: 17 Winning Solutions That Could Save the Planet," Fast Company, www.fastcompany.com/90329204/world-changing-ideas-2019-17-winning-solutions-that-could-save-the-planet.

[8] Clendaniel, "World Changing Ideas 2019."

[9] Vaya Space, "Eco-Friendly," www.vayaspace.com/ecofriendly.

Opportunities

There are many opportunities to use space for corporate responsibility to mitigate the climate crisis. By displaying corporate responsibility through space activities that improve our environment, companies can develop brand stories that resonate with their audience. Brand stories generate content for social media, earn positive stories in the news, and give reasons for customers to choose them for purchases.

There are several platforms that can guide this marketing journey. Companies can use data to develop an eco-friendlier supply chain, enter into a sustainability challenge or competition, develop a new product that is Earth-kind or cleans up pollutants, and the list continues. Actions can be small steps or giant leaps that are budget friendly or large committed investments. Companies can pick the ones that fit their industries and that they can sustain.

They can be creative with what they choose to do and make sure that it can be fiscally rewarding. Climate-related strategies cannot help our world if the company goes bankrupt in the process. A little ingenuity and a dedication to environmentally friendly endeavors can reap large rewards for everyone involved. They can enlist public support and make the public a part of the story. The public will promote such initiatives and become staunch fans of such activities.

A Word of Caution

When using this strategy, companies should make sure that their actions are authentic and that their intentions are noble. If companies do not follow through or are found untruthful, it can destroy any trust and be almost impossible to recover from the damage. This is an emotive subject to which people connect their identity. It is a very personal relationship. Breaking trust can result in violent reactions or erase any real effort that such companies have made. It is easy to become a target for negative attention.

Conclusion

Developing corporate responsibility-focused programs that mitigate the climate crisis using technologies resulting from the space industry can develop a brand story in three powerful categories that provide marketing content that may resonate deeply with the public. These marketing trifecta strategies create a winning solution for companies, their customers, and the environment.

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About the Author: As an author of the book, *Space Marketing, Competing in the New Commercial Space Industry* and as the host of the Space Marketing Podcast, Izzy House aims to be a voice that helps to guide businesses through the concepts of marketing. With an extensive marketing background and three marketing degrees, she turns the lens of marketing onto the space industry. Armed with 20+ years of experience in public affairs, outreach, and marketing, Izzy aims to empower space companies and further their dreams of space exploration.

Editors' Notes: First-time contributor Izzy House is a marketing expert who focuses on the space industry. Her paper offers an overview of promotional opportunities available to many commercial space companies, and suggestions for how to take advantage of them. Ranging from the climate crisis to corporate responsibility, she focuses on making a meaningful impact rather than mere advertising strategies. Her prospective approach exemplifies the sort of optimistic stance we will all need to bring to future endeavors in order to work toward shared success in the growing space economy. ***Mark Wagner and Gordon Arthur.***

A Space for Art in Space

By Priyanka Das Rajkakati

> "But without fallibility there is no art. And without art there is no truth."—Alastair Reynolds, Zima Blue.

Prologue

Carl Sagan, the popular planetary scientist, famously said: "We are a way for the cosmos to know itself."

Humans have endeavored since the beginning of civilization to explore and document our understanding of Nature and our Universe. Through philosophies and, in modern times, also through rigorous scientific theories, we have learnt to trust the logic-based structural approach towards understanding and explaining these phenomena, from the processes that sustain life on Earth to how our "pale blue dot" spaceship constantly interacts with the vast universe—although seemingly isolated in our limited intuition for dimensions, with the nearest celestial body, our Moon, more than 300,000 km away.

This article does not get into the debate of what exactly is considered art; however, in view of the need for an introduction, here is the author's understanding of it: *art* does not have to be aesthetic, reduced to visual reproductions of everyday life, but instead, it is about portraying ideas in an unconstrained manner, showing a way out of the bubble of structured thought, questioning practices and censorship, pondering upon possibilities without the burden of logical proof. Most importantly, it is about reminding us of our humanity, our cultural diversity, our lessons from history, and our right to dream about our future.

Before learning to write, as children, we learn to draw—something that can be seen across the scale of time with, as anthropology shows, the first cave drawings predating the first scripts. Art in the form of music and dance was also an accessible way to propagate our histories in the past and to engage the public, a tradition that has continued. Indeed, *art* has taught us to think. There is a popular joke in science about how biology seems to be just applied chemistry, chemistry is but applied physics, physics is practical mathematics, which in its turn, is applied philosophy. Well, could philosophy be further considered an attempt to structure art?

In fact, it seems to be a fairly recent phenomena, as society has become driven towards specialized workforces, that we have forgotten that the human mind does not segregate thought according to domains of expertise. Why then, have we become a society that expresses confusion when we hear a phrase such as "the intersection of art and science"? The author would like to restate that art allows us, simply, to express ourselves—and that it transcends any set definitions. It is a very natural state of our thought process, and it can work in tandem with science to create fantastic outputs: (i) Albert Einstein, arguably the world's most adopted image of a scientist, was known to play the violin (how well is an matter of unimportant debate), (ii) Leonardo da Vinci, on the other hand conventionally categorized as an artist, was known to experiment with scientific theories and engineering, from his experiments on human anatomy to proposing aircraft designs way before his time, (iii) the father of the Indian nuclear program, Homi Bhabha, was a talented painter, (iv) Samuel Morse, who invented the Morse code, was equally accomplished with brushes, and (v) would Galileo Galilei have been able to communicate as effectively about his telescopic data on the Moon without his able-handed sketches of what he saw?

Artists, no matter how one may choose to define their oeuvres, have always played an important role in society. It is therefore essential, first, to acknowledge their place in civilization (present or future), and then to allow them some space right from the development process of our future interplanetary societies, not only to bring to the forefront revolutionary ideas, but also to break through the inertia of human memory and reinstate forgotten or even deliberately suppressed narratives.

Ultimately, this might be what separates us from high-functioning interstellar hybrid robots.

A Retrospective Look: The Role of Art in Space Exploration

According to the author's social experiments, a common reaction to when art and space are used in the same phrase is, "Oh, how do the two go together? Isn't space all about rocket science? The place of artists in this conversation must be something fairly new." But is that really the case?

This section presents an introduction to how artistic expression—and here let us also include dance, music, culture, and of course, paintings and installations—has played a major role in space exploration, such as inspiring designs and providing material for thought, often from behind the scenes. Let's start with astronauts themselves.

Artistic and Cultural Activities in Space

One of the toughest jobs today in any extreme environment is that of astronauts, who also embody the very idea of a career in space, which is why highlighting their engagement in artistic and cultural activities during spaceflight is so important. Indeed, although we hear often about how highly precise and meticulous the daily routines of astronauts tend to be, such environments have not been sterile to artistic and cultural imprints.

The first painting in space is said to have been that by cosmonaut Alexei Leonov, painted during his Voskhod 2 spaceflight in 1965. The fourth human to walk on the moon, NASA astronaut Alan Bean, became a full-time painter after his retirement, documenting his experiences in space. ESA astronaut Thomas Pesquet fascinated audiences on Earth by playing his saxophone from the International Space Station (ISS) and also by sharing beautiful imagery of the Earth from his time in space. Another space traveler captured the minds of people from a part of the world perceived as rather obscure yet home to 31 million people (including the author's parents)—Assam; NASA astronaut Mike Fincke, whose wife is Assamese, performed the traditional dance of Bihu from the ISS in 2004.

First painting in space by Alexei Leonov

Thomas Pesquet and his saxophone from the ISS Cupola

Is Anyone Out There, by Alan Bean

Mike Fincke dancing Bihu in Space inside the ISS.

Space-Inspired Art: Other Earthlings

There is barely any argument to develop here.[1] Most of us, who have not had the opportunity (yet) of going up into space to have a first-hand look, have, nevertheless, grown up sketching stars on paper with felt-tip pens. Our early ancestors were not much different: if you look at the ancient cave-painting known as the Lascaux Shaft Scene, found in a cave in France, it has been speculated that it depicts not just images of animals and a dying man, but also a comet strike that might have occurred around that time in 15,200 BCE.[2] Indeed, the relationship between the cosmos and our civilizations is ancient and

[1] R. Miller, *The Art of Space: The History of Space Art, Art, from the Earliest Visions to the Graphics of the Modern Era* (Minneapolis: Zenith Press, 2014).

[2] M. B. Sweatman and A. Coombs, "Decoding European Palaeolithic Art: Extremely Ancient Knowledge of Precession of the Equinoxes," *Athens Journal of History* 5, no. 1 (2019): 1–30.

deep, as archeology and anthropology have shown, with depictions of the Sun, the Moon, and the stars eventually being adopted as symbols of power—religious or administrative.

Fast forward to today, contemporary artists, including filmmakers, have been inspired by the universe, working in tandem with scientists and engineers to depict their ideas in ever more realistic ways. The recent images from the James Webb Space Telescope have already been the subject of much artistic interpretation, with NASA even inviting select artists to see it in person before its launch and to create exhibits for the Goddard Visitor Centre in 2017. Finally, just because it is such a fantastic painting, let us also look at van Gogh's Starry Night. His genius is so great that scientifically verifiable fluid dynamics can be detected in his swirls, which depict the cosmos at play.[3]

Lascaux Shaft Scene

van Gogh's Starry Night (1889)

Art-Inspired Space Technology

Yes, art has been inspired by the heavens, but these very imaginative outcomes can be argued to have helped to develop scientific theories in return. The ability to depict astronomical observations has helped us to develop astronomy and navigation, and timekeeping has improved as a consequence—today, the most precise atomic clocks are on board navigation satellites that keep us all coordinated, and they are important for everything from stock exchanges to precise navigation. Art might have also fueled a desire for human spaceflight in our collective imagination. From ancient times, various cultures have depicted their heroes and gods with the ability of flight, and artisans have immortalized these imaginary depictions as sculpture and paintings, often inspired by nature's own wing designs. The author would not make any claims here, but drop a simple question: could it be these works of art motivated us to test it on ourselves?

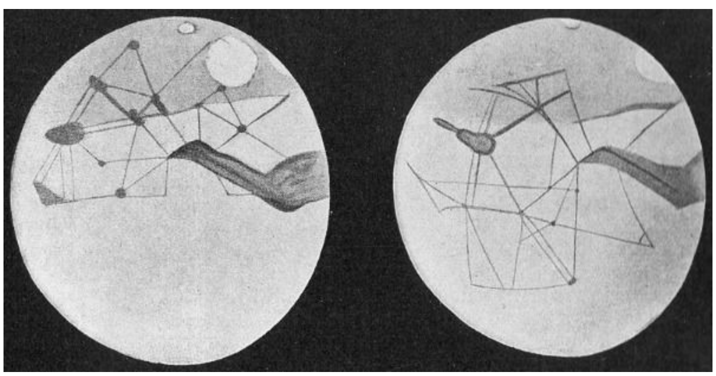
In this period of modern-day rocketry, spacecraft designs can even be traced back to ideas proposed by science fiction authors, such as Jules Verne, who wrote *From the Earth to the Moon* in 1865. There is also evidence to suggest that spaceflight pioneers such as

[3] P. Ball, "Van Gogh Painted Perfect Turbulence," *Nature News*, July 27, 2006, www.nature.com/news/2006/060703/full/news060703-17.html.

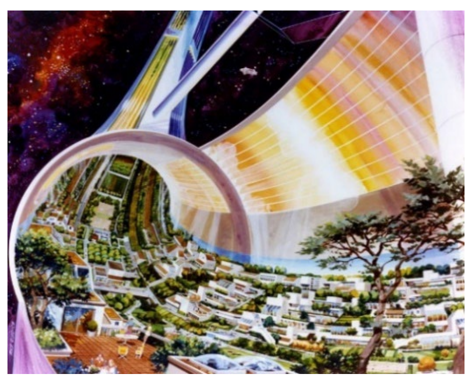
Konstantin Tsiolkovsky, Hermann Oberth, and Robert Goddard were quite influenced by speculative novels published in Russia, Germany, and the United States in the nineteenth century.[4] Even the dream of living on Mars has existed since at least the end of the nineteenth century, with H. G. Wells's 1897 novel *War of the Worlds*, and the apparent discovery of canals on the red planet, fueling ideas of Martian aliens. Percival Lowell, driven by his obsessions with finding intelligent life on Mars, drew several images of these canals, and he founded the Lowell observatory in Arizona, where Pluto was discovered in 1930 by astronomer Claude Tombaugh (whose ashes were aboard NASA's New Horizons spacecraft, headed to Pluto, making it the longest known post-mortem flight).[5]

Science-fiction films should also be lauded for taking art to another level of storytelling. The first serious science-fiction film *Woman in the Moon*, directed by Fritz Lang in 1928, presented the basis of rocket travel to a mass audience for the first time and even had Oberth as a technical advisor on a multi-stage rocket design. *2001: A Space Odyssey*, the 1968 Stanley Kubrick film written by Arthur C. Clarke, is widely regarded as one of the most influential films of all time, noted for accurately depicting space flight and pioneering special effects, and it continues to inspire generations of researchers in AI and space technology.

Artists have also been directly part of space research. In the 1970s, three space colony summer studies were conducted at the NASA Ames Research Center during which several artistic renderings were proposed to help to dream future space technologies through art.[6] Some of these images are today so present in our experience of space that they seem instantly very familiar, such as the *Toroidal colonies* series by artists such as Don Davis and Rick Guidice, which further inspired more creative works (like the movie *Interstellar*).



Martian Canals, by Percival Lowell



Toroidal Colonies, by Rick Guidice

[4] A. A. Siddiqi, *The Red Rockets' Glare: Spaceflight and the Russian Imagination, 1857–1957*, Cambridge Centennial of Flight (Cambridge: Cambridge University Press, 2010).

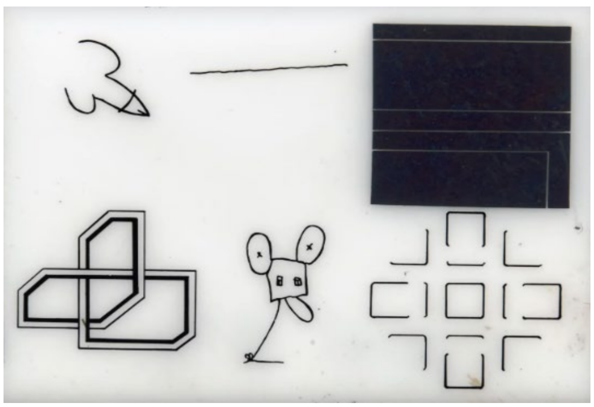
[5] www.businessinsider.com/cremated-ashes-pluto-space-probe-2018-10.

[6] H. Hotovy, "NASA and Art: A Collaboration Colored with History," NASA History, 2017, www.nasa.gov/feature/nasa-and-art-a-collaboration-colored-with-history.

Actual Art in Space

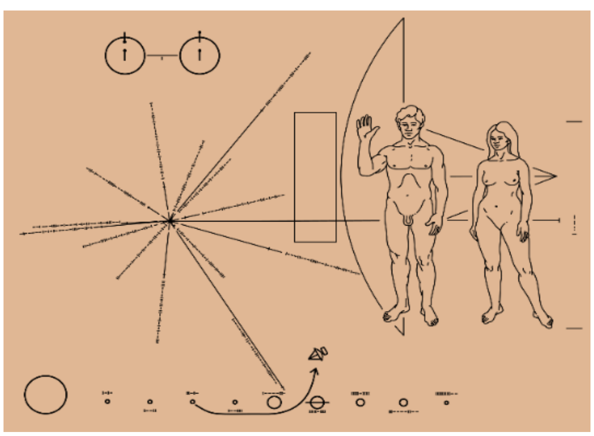
So far, we have seen not only how the vast cosmos has inspired artistic expression, but also how art has in turn inspired actual technological advancements. However, the concept of space art would be incomplete without including works that have actually gone into space, crossing the Karman line of 100 km altitude. Here is a list, by no means exhaustive, of a few such works, which the reader is invited to explore further.

In the early days of human spaceflight, apart from Alexei Leonov's painting mentioned earlier, astronauts have also had the task of installing artwork in space. There is some debate on whether Apollo 12 (1969) carried with it *The Moon Museum*—a plate containing art by six well-known artists of the time including Andy Warhol.[7] Then in 1971, the Apollo 15 astronauts placed *Fallen Astronaut* on the lunar surface, a 3.5-inch aluminum sculpture created by Paul van Hoeydonck commemorating the then 14 astronauts and cosmonauts who had perished for the sake of space exploration, making it the first sculpture in space. The Pioneer Plaques on board Pioneer 10 (1972) and Pioneer 11 (1973), and the Voyager Golden Records on board Voyager 1 and 2 (1977), which had Carl Sagan as one of the ideators, have also taken a part of human culture into interstellar space.



The Moon Museum (1969)

Fallen Astronaut (1971)



Pioneer Plaque (1972)

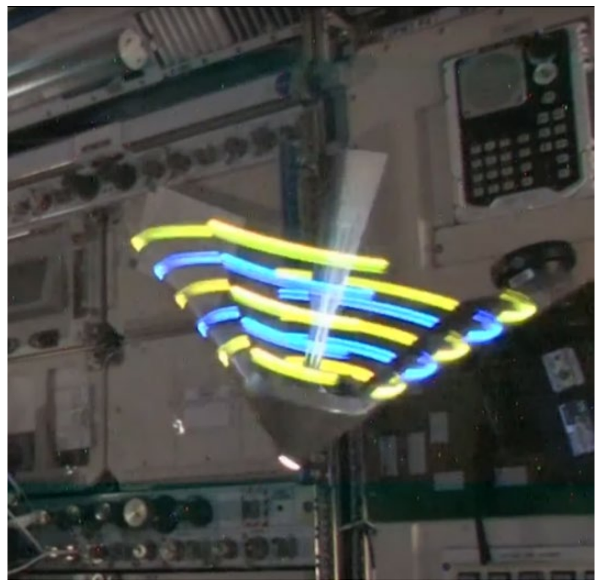
Voyager Golden Records (1977)

[7] *History Detectives: Who is John F.?* [Movie], PBS, 2010.

The microgravity environment has also generated much curiosity on how materials might behave in such extreme environments. In 1986, four oil paintings by Ellery Kurtz were placed on board NASA's Columbia Space Shuttle for a five-day orbit around the Earth to test how pigments and paintings were affected by spaceflight, as well as how aesthetic pleasure might change the experience of being in deep space. In 1993, *Cosmic Dancer* by Arthur Woods was launched to the Mir Space Station—the first 3D artwork to be specifically conceived for and officially realized in a space habitat, with the aim of investigating the properties of sculpture in space. In 2009, light artist Takuro Osaka sent *Spiral Top*, a device that spun and made colorful trails with mounted LEDs in microgravity, aboard the ISS. Richard Clar's 2019 work *Giant Step*, that bounced laser signals off the Apollo 11 reflector on the Moon, is an art-science contemplation via the medium of space.

First oil paintings in Earth Orbit (1986)

Inner Telescope, ISS (2017)



Spiral Top, ISS (2009)

Cosmic Dancer (1993)

Enoch (2018)

Art has also been sent into space to reflect on part of our histories and philosophies. In 2017, Eduardo Kac's work, *Inner Telescope*, was assembled in space on the ISS by astronaut Thomas Pesquet following the artist's instructions, and it invited the spectator "to rethink our relationship with the world and our position in the Universe." 2018 was an eventful year for artistic reflections in outer space. Tavares Strachan's ENOCH launched into a sun-synchronous orbit via the Spaceflight SmallSat Express mission, aiming to bring to light the forgotten story of Robert Henry Lawrence, Jr., the first African American astronaut selected for any national space program (but who never flew to space until Strachan put him there). Nahum's *Contours of Presence* made its way to the ISS, which audiences could actually interact with in real time on Earth. 2018 also saw the launch of *Orbital Reflector* by Trevor Paglen, which ressembled a satellite but was purely an aesthetic object in space, generating debate on who has the right to send items into space (astronomers were not happy with the possibility of the reflective surface of the artpiece obstructing scientific observation). Finally, Thomas Pesquet himself starred in *16 Levers de soleil* (*16 Sunrises*), a film with scenes shot on the ISS that weaves a dialogue between the astronaut and the visionary work of French polymath, Antoine de Saint-Exupéry.

Wait, Aren't We Missing Entire Sections in this Narrative?

The examples presented above are what one would typically find after a simple search on the internet. So far in this article, not a single woman has been mentioned. Now, here is a social experiment: how many readers actually noticed this—did you?

To start with, the film *Woman in the Moon* mentioned earlier, which has been promoted to date as Fritz Lang's work, was, in fact, written by his wife, Thea von Harbou, based on her novel *The Rocket to the Moon*. In fact, there is a general problem of acknowledgement of women artists, not just in the space industry. A great resource on that research is a recent book by Katy Hessel titled *The Story of Art Without Men*.[8] For example, the Royal Academy of Arts, London, has never hosted a solo exhibition by a woman in its main space. More specifically in the domain of space, if one were to look up the Wikipedia page titled "List of Space Artists," among the long list of people featured including astronauts, the representation of women is quite dismal. Even in the few residencies that do exist in the space industry, women are not strongly represented, and nor do they manage to secure continued funding.

Therefore, let us continue the conversation and delve into contributions of women in the field of art and space. To start with, there are two incredible NASA astronauts, Nicole Stott and Karen Nyberg, who have also established their names as artists. Nicole has been creating works inspired by photos she took from the ISS, and she also started the Space for Art Foundation—a mission with the aim of using community art projects to inspire children in hospitals, refugee centers and schools around the world. Karen Nyberg, the fiftieth woman in space on her first mission in 2008, is also a textile artist and sparked a

[8] K. Hessel, *The Story of Art Without Men* (London: Penguin, 2022).

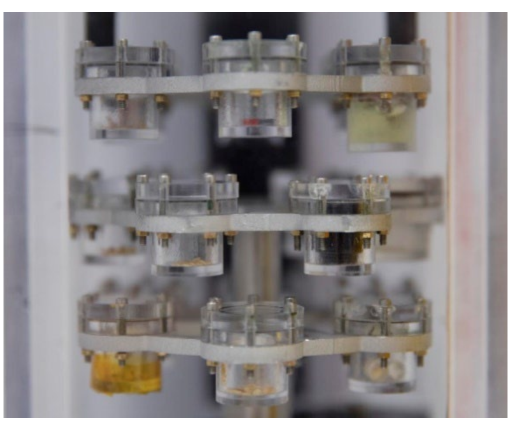
worldwide quilting project while sewing in the ISS. Continuing the tradition, current NASA astronaut candidate, Zena Cardman, is an Antarctic adventurer as well as a trained poet.

Contemporary women artists have also been sending their art to space. Xin Liu, Arts Curator at the MIT Media Lab Space Exploration Initiative, has worked on several interdisciplinary projects, including performing on a zero-G flight, sending her wisdom tooth to space, and curating the MIT Sojourner 2020 Payload Project. For the latter, one of the nine selected artists was Adriana Knouf, who identifies as a transgender woman, and whose payload titled *TX–1* contained a sculpture made of hormone replacement medications, marking it the first-known transgender experience to orbit the earth, according to Knouf.

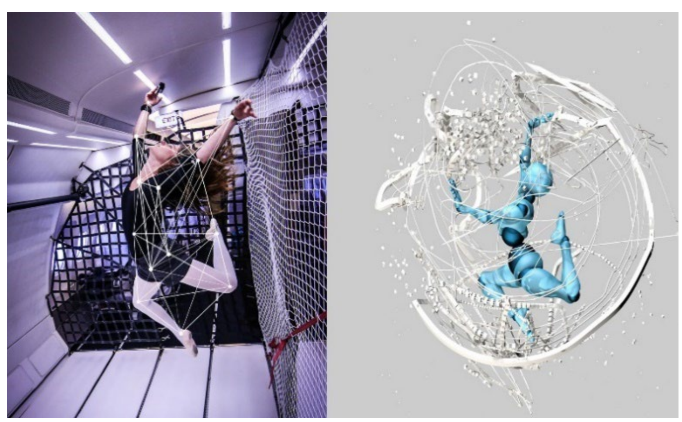
When it comes to music and poetry, Maya Angelou's poem, *A Brave and Startling Truth* was flown on the NASA Orion spacecraft during its first flight in 2014. French designer, Nelly Ben Hayoun, created the International Space Orchestra, composed of famous musicians, scientists, and astronauts, and which has sent a record to the ISS. French duo Jeanne Morel and Paul Marlier performed a dance sequence in Zero-G in 2017 while tracking her movements to test how physical constraints are different in microgravity.

The End of an Era, textile art by Karen Nyberg

The Wave, mixed-media work by Nicole Stott



Sojourner 2020 (MIT Media Lab)



Jeanne Morel's dance in zero-gravity

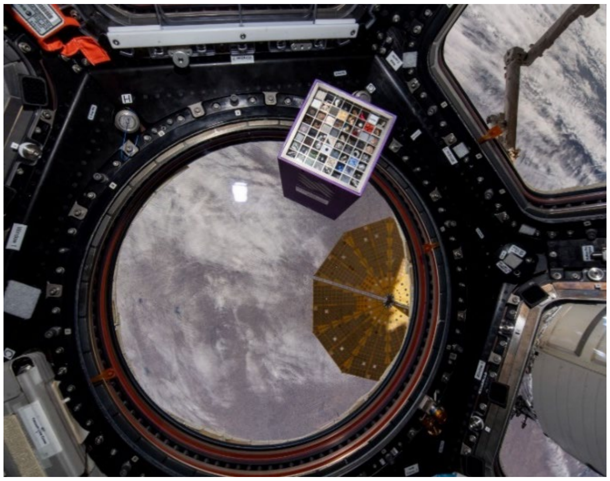
It's also worth mentioning the space-inspired works of pioneering artists such as Daniela de Paulis (visual Moonbounce technology, which even inspired Richard Clar) and

Sarah Jane Pell ("aquabatics"). Finally, Peggy Hollinger, not an artist but the International Business Editor at the *Financial Times*, collaborated with graphics journalist Sam Learner to write an engaging piece called *How Space Debris Threatens Modern Life*, which is a piece of art in itself, showing how artistic visual storytelling is an effective medium of communication.[9]

Moon Gallery

This brings us to the Moon Gallery Project, the idea behind which is to create an international collaborative gallery of ideas worth sending to the Moon to develop a culture for our future interplanetary societies. With the intent to launch a hundred artifacts to the Moon within a compact format of a 10 x 10 x 1 cm plate on a lunar lander exterior paneling, it challenges artists to fit their work into a 1 cm^3 space. Why miniaturized rather than full sized? Because, according to estimates, it costs a million euros/kg to send anything to the Moon.

The Moon Gallery has indeed been a game-changer in giving visibility to women artists. Joining an idea conceived in 2018 by Alexander Zaklynsky,[10] the Moon Gallery is being curated by two visionary young women, Anna Sitnikova and Elizaveta Glukhova, and over half the artists are women, including established names such Aoife van Lindel Tol (the first ESA–Ars Electronica artist-in-residence), Lakshmi Mohanbabu, Beyond Earth (an all-female international transdisciplinary artist collective), Lisa Pettibone, Kristina Okan, Paula Romero Franco and Minna Philips (and to a much humbler degree, the author of this article herself).



Moon Gallery on the ISS (courtesy of the Moon Gallery Foundation, Nanoracks, and NASA)

Moon Gallery up close

[9] P. Hollinger and S. Learner, "How Space Debris Threatens Modern Life," *Financial Times*, June 8, 2022, ig.ft.com/space-debris/.

[10] A. Zaklynsky, A. Sitnikova, and B. Foing, "Developing Structures for an International Art Gallery on the Moon," Paper given at the 42nd COSPAR Scientific Assembly, Pasadena, CA, July 14–22, 2018. zaklynsky.com/AZ-ELS-MoonGallery.pdf.

The invited artists also include Eduardo Kac—the artist behind *Inner Telescope*, mentioned earlier, Marcus Neustetter—a South African artist and cultural activist, the artist collective Christophe Draeger and Martin Frei, along with Masahito Ono—who was also one of the Sojourner 2020 artists.

ISS Mission

Although the initial lunar mission was planned for 2022, the global pandemic lockdown introduced understandable delays. The ISS mission was thus proposed as an intermediate step, and as a learning phase for a future lunar launch. Indeed, the Moon Gallery was successfully launched to the ISS on February 19, 2022, making it the first organised viewable art gallery in space. It was carried on board the Cygnus spacecraft, launched using a Northrup Grumman Antares launch vehicle, via the NG–17 ISS Resupply Mission. Consisting of 65 artworks in total on an 8 x 8 grid, the gallery is as of November 2022, still orbiting the Earth within the ISS, installed inside a Nanoracks Nanolab and serving as a set of moving targets for camera observations and performance tests. Truly qualifying as an art-science collaboration, the gallery not only offers a diverse range of materials and behaviours for the camera to detect, but it will also allow the artists to learn about the performance of their artworks in microgravity when it is returned to Earth in December 2022.

A Prospective View on Space and Art

According to Lawrence G. Downing, "Science and machines make Space travel possible; humans add soul. Those who manage space travel need to be as creative to care for the humans as for the hardware."[11]

Art should not be treated as a standalone domain—it is not about reducing the work of artists to creating beautiful paintings to put up on the walls of the first human lunar bases after they have been set up. It is about integrating artistic philosophies iteratively into current technological designs. Artists should be allowed to work in tandem with trained engineers and scientists right from the conception phase, questioning not just the optimal ways of designing our next spaceships, but also the consequences of it, something our hyperspecialized workforces are not taught to question. Indeed, today, more brilliant minds are trying to solve the issue of space debris collision avoidance, rather than avoidance of debris generation in the first place. Perhaps art could help reawaken our conscience, which seemingly has been muted once again in the face of the excitement generated by technological boom.

The previous section gave a few examples of various projects that have explored the place of art in our efforts towards space exploration, highlighting the complex nature in which artistic reflection is interwoven into the fabric supporting spacecraft designs.

[11] Lawrence G. Downing, "Long-Term Space Inhabitants: Their Needs, Care, and Support," *Journal of Space Philosophy* 9, no. 1 (2020): 9.

Although it is incredible that art has even found its way into orbit, there is a very jarring difference between who finally gets access to these opportunities—artists from underdeveloped countries are just less likely even to be aware that they could dream of seeing their work going to space. There is an entire portion of our present societies whose perspectives are not being reflected (it has been hard to write this article without giving only Western-centric examples), with the ones without voices being the ones who are neglected and hence suffer the most. Even Sagan's Pioneer plaques attracted a lot of controversy for depicting a highly one-sided picture of humanity as the universal image of it (whether aliens would be able to decrypt any of the messages in the first place is another debate). As artist Nahum said during an interview, "artists must be included in the conversation about how we explore space or else humanity—namely rich countries with well-funded aerospace programs—risk[s] making the same mistakes the colonizing empires made in the past."[12]

The recent COVID lockdown has provided another great example of how important the arts are to our core needs as a species—the global pandemic put a lot of technical jobs on hold or out of business, but creative fields prevailed, offering hope and entertainment in grim times, bringing people and ideas together in the face of isolation. 2021 was also apparently a record-breaking year for the aerospace industry, with over $10 billion invested from private-sector funding.[13] Therefore, now is the time to provide opportunities for cross-disciplinary collaborations, in which artists could be instrumental in pitching innovative ideas, not just for businesses with great returns on investment, but also conscientious projects that keep the health of the planet in mind. Where does the future lead us from here? What could be done differently?

Nurturing the Work of Artists—A Work in Progress

As we see in general, the first hurdle for artists is acknowledgement of their work, which requires legitimate platforms: exhibitions, residencies, even support through conferences. Next, to ensure the continuous creation of such opportunities, there needs to be more financial support, which is still very difficult for artists to secure. The amount of funding decides availability of and access to resources, as well as contributing towards the artist's commission (one has to live and pay one's bills after all). This requires more reliable support structures, the setting up of which depends on demand, which ultimately is linked to the acknowledgement of the work of artists—this is a vicious feedback loop that needs to be addressed.

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[12] D. V. H. Maldonado, "The Artworks Floating Above the Earth," BBC Culture, 2018, www.bbc.com/culture/article/20181214-the-artworks-floating-above-the-earth.

[13] R. Brukardt, J. Klempner, and B. Stokes, "Space: Investment Shifts from GEO to LEO and Now Beyond," McKinsey & Company, 2022, www.mckinsey.com/industries/aerospace-and-defense/our-insights/ space-investment-shifts-from-geo-to-leo-and-now-beyond.

There are several initiatives that may help to bridge this gap and to include conversations and perspectives not just from women, but also from the entire spectrum of human diversity, especially people from emerging or non-spacefaring nations. NASA has already shown recognition of the power of the arts in harnessing public engagement, and it is encouraging to see this trend spreading to other space agencies and even private companies. In France, the CNES has a cultural laboratory called *Observatoire de l'Espace* (Space Observatory), which gives artists access to its archives to curate works that make space more accessible to the public. Private space industry is also becoming actively involved in promoting the arts through various innovative initiatives. Kinéis, created in 2018 by CNES and CLS to develop the next-generation Argos IoT tracking system, has launched a competition to invite children, the public, and artists to contribute works on the theme of Earth observation and climate change, which will be etched onto some payloads onboard the twenty-five satellites it is launching in 2023. Planet Labs has been sending artwork onboard its satellites since the first launches.

Residencies and art biennials have also started to allow more space-themed culturally diverse narratives on their stages, providing a platform for lost histories. A beautiful example is the film *Afronauts*,[14] a short film showcased in the 2014 Berlinale, based on the real-life vision of Edward Makuka Nkoloso from Zambia, who dreamed of sending Zambians to the Moon back in the sixties. Then, in recent years, the European Geosciences Union has been inviting artists for residencies during its annual General Assembly, in which artists can interact with participating scientists and create works inspired by scientific abstracts. This collaboration not only allows the artists a fresh canvas to experiment on, but also provides scientists a creative method of promoting their work.

The International Astronautical Congress (IAC), arguably the largest space conference, has also been including artistic and cultural dialogues via various events and sessions, such as the ones organized by the Committee for the Cultural Utilisation of Space (ITACCUS). This year's IAC in Paris also saw a next-generation plenary on space and art, which had a panel composed of five young women artists practicing various media and forms, from dancing in parabolic flights, to using painting as a medium of engagement. On the other hand, the Space Generation Advisory Council, which represents the voices of young space professionals and students (aged 18–35) has also recently started an art gallery initiative (curated by the author), inviting the youth from across the world to share their perspectives on various social themes via the medium of art.

Other establishments such as Nahum's Kosmika Institute, the MIT Media Lab and the Space Ecologies Art and Design group, are examples of a transdisciplinary and cross-cultural platforms exploring diverse narratives. Last but not the least, the Karman Project, a nonprofit, independent and global foundation, is also providing opportunities for accomplished young leaders from different fields in the space industry to come together

[14] N. Bodomo, Director, *Afronauts* [Movie], 2014.

and collaborate on impactful projects, often with artistic outcomes geared towards positively impacting society, inviting perspectives from around the world including India, the African continent, and South-East Asia.

This list could go on, which is indeed a very positive conclusion, but clearly more such initiatives are required, allowing more unheard voices to emerge from across the world.

Is Artistic Fiction Approaching Reality?

Before concluding this article, let us have a quick look at how new-age creative technologies are allowing for innovative ways of bringing the space experience to Earth, slowly bridging the gap between the privileged who are able to go to space and those confined to the earth's crust. An example is the *Space Explorers: The ISS Experience* project by Felix & Paul Studios in association with Time Studios, filmed entirely in space, and which can be viewed using a virtual reality headset. The upcoming Metaverse is also taking immersive experiences to the next level, with a few companies even combining gaming with decentralized non-fungible token assets.

Earlier we also saw how artistic meanderings from the 1970s about possible space structures were seen years later in science fiction movies, perhaps even inspiring future public and private space station concepts such as Blue Origin's Orbital Reef and the Space Perspective stratospheric balloon project. Erstwhile conceptual fields of study such as space architecture are now over taking the concept of space habitats by storm, with some great designs being proposed by visionaries such as Barbara Imhof.

The future of space exploration is bright and exciting! The artistic fiction of going and living on other planets might soon be a reality. However, we have to work in tandem with real-world challenges on our perfectly habitable planet Earth, such as climate change, as well as tackling social issues such as the ongoing lack in diversity and inclusivity in the space industry. Artists have always played an important part in space exploration by having daring conversations, and now they are even more important as we branch off into the next phase of becoming a multiplanetary society. We will need fearless visionaries, as well as effective communicators, to carry with us the human experience from all spectrums and backgrounds to tomorrow's new off-planet societies, advancing together towards a sustainable future. We will need artists. In the words of Roger Malina, astrophysicist and also executive editor of Leonardo Publications, "Let's transfer desirable knowledge to outer space. Let's not transfer the worst aspects of human cultures."[15]

How do you imagine our future interplanetary societies?

Epilogue

On February 14, 1990, Voyager 1 sent us a photo of our planet from six billion kilometers away, after travelling nearly thirteen years. In the photograph, our Earth's

[15] Roger Malina et al., *Space Without Rockets*, UV Editions, 2022, uveditions.com/space-without-rockets/.

apparent size is less than one pixel: an inconsequent "Pale Blue Dot" in the vastness of space, as coined by Carl Sagan.

It's incredible how on that tiny dot, there is life, and one highly destructive species, which has otherwise developed the capacity to imagine, build, launch and continue communicating with, even after forty-three years, a space probe that is now in interstellar space. Perhaps for anyone out there, it's a primitive achievement. But to every one of us here on our vibrant planet, bustling with life, oceans, clouds, forests, tardigrades, blue whales, volcanoes, icecaps, viruses, emotions, politics, cinema, an international space station … it is our entire existence. Tomorrow, a large asteroid impact might obliterate us and no one, out there, would probably know or care.

Till we find other lifeforms, our species will continue to explore for itself, satisfying its own natural curiosity. Space helps us to dream about the far reaches of our universe, and also to develop tools for cross-dimensional information exchange: at the same time as planning human lunar (and soon, Martian) missions, we are also using this technology to monitor the Earth and the environment—floods, biodiversity, high-frequency trading—to make (most) lives better.

At the heart of it all, it is art that fuels our imagination.

It is art, our mother tongue, which should not be forgotten.

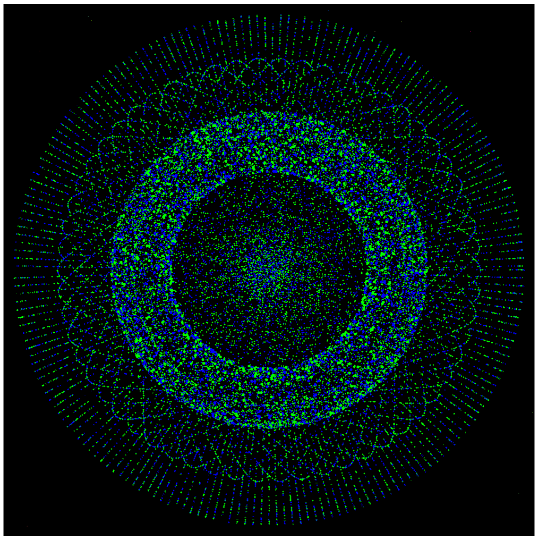
Therefore, we need some space for art in space.

Acknowledgements

I would like to start by thanking my advisors for allowing me bandwidth to pursue artistic side projects during a very technical thesis on signal processing estimation, culminating in a PhD (which in fact stands for *philosophiae doctor*, making me wonder if that means I have a degree in philosophy—the world today does seem to give a lot of importance to degrees). Next, I am eternally grateful to the ITACCUS team for their wonderful projects and the work they are doing towards the promotion of the arts in the space domain. I would also love to thank the members of the Karman Project for involving me in some amazing cross-disciplinary projects, and all the artists, scientists and basically anyone who has had the patience to discuss art in space with me—including Sudheer Kumar N, Mathieu Weiss, Susmita Mohanty, Yvette Gonzalez, Jean-Marc Deshouillers, Hélène Huby, and of course, Mark Wagner, and a long list of many others including family and friends. Finally, heartfelt thanks to Dr H. Bhoosnurmath for his insights.

This article is a non-exhaustive timestamp of my research on the place and evolution of the arts in the space industry and is probably quite biased based on my experiences. On one hand, while I have been amazed by the artwork and creative initiatives one finds in the space industry, I have also been at times a bit taken aback by how much work still needs to be done, especially when it comes to opening access and inviting more diversity. But the progress is very inspiring! In ten years, I would love to come back to this article and see how my understanding has evolved.

Appendix A: Journey of an Artwork—*Bhédadipika*



Sometime in the summer of 2007, I was working on a high-school Computer Science project in C++, when I became, quite intensely, obsessed with how we could use basic code to create moving images on a primitive DOS-like screen. This is how *Star Cities/Organized Worlds* was born—mysterious forms created by mathematical equations called hypotrochoids.

I had this fleeting thought that in a galaxy cluster far, far away, a hyper-intelligent society with the technological capability of manipulating the formation of galaxies themselves would probably be exploiting the humble hypotrochoid for inspiration for harmonious forms. I continued to work on the simulations, going back every now and then, fiddling with the parameters, adding layers, and combining some. It was some fifteen years later that this experiment with *art* and mathematics finally found an exhibition space, and what a grand one at that—Space itself.

I attended my first IAC in 2018 in Bremen, where, enthralled by all the space-themed events, I also wondered if there was a session on *art*, and lo and behold, I turned around and there it was—a notice on a door to an auditorium which said, "Space and *Art*—starting in 10 minutes." The rest, as they say, is history. This is where I met the first bunch of space artists in my life—members of ITACCUS—and discovered the call for submissions for the Moon Gallery project. I spent a lot of time reflecting on the questions the project wanted to answer: What did it mean to develop culture for an interplanetary society?

What was the message I wanted to send to the Moon for these future societies? The answer was right in front of my eyes. I wove a story around my imaginary galaxies for finding them a place among society and created my artwork: *Bhédadipika*, or *An Illustration of Duality* in Sanskrit. The complete artwork consists of both physical hand-drawn elements and a chip containing my hypotrochoids. To be part of the Moon Gallery, the artwork was further shrunk to fit into a 1 cm^3 box, playing upon several notions of duality such as constraint/freedom, light/darkness, minute/infinite, reality/illusion, and randomness/intent.

Bhédadipika has since been showcased in several exhibitions, most recently as part of the Moon Gallery on the ISS in February 2022. Today, when I see the ISS pass above me in the sky, I close my eyes and imagine myself connecting with my skin cells, which must still be embedded in my hand-made work. After all, far more morbidly, someone once derived spiritual meaning by sending Clyde Tombaugh's ashes on board *New Horizons*.

Appendix B: Artistic Beauty in Mathematics

Curious about hypotrochoids?

A hypotrochoid is a roulette traced by a point P attached to a circle of radius b rolling around the inside of a fixed circle of radius a, where P is a distance h from the center of the interior circle. The parametric equations for a hypotrochoid are:

$$x = (a - b)\cos t + h\cos\left(\frac{a - b}{b}t\right)$$

$$y = (a - b)\sin t - h\sin\left(\frac{a - b}{b}t\right)$$

A sister curve is the epitrochoid, a roulette traced by a point P attached to a circle of radius b rolling around the outside of a fixed circle of radius a, with h the distance from P to the center of the rolling circle:

$$x = (a + b)\cos t - h\cos\left(\frac{a + b}{b}t\right)$$

$$y = (a + b)\sin t - h\sin\left(\frac{a + b}{b}t\right)$$

An epicycloid is simply an epitrochoid with $h = b$.

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About the Author: Dr. Priyanka Das Rajkakati is a French aerospace engineer-cum-artist, born in India, whose work involves mixing science, art, and space. She explores how *art* can be a powerful medium in encouraging the space industry to think in terms of long-term sustainability and the health of our one planet. Her work draws inspiration from her Assamese roots and her travels, from Brazil to Hawai'i and next: Antarctica (2023). She has won numerous awards, including a place in the Forbes India 30 under 30 list, and she is a Karman Fellow. Her work can be found at www.PriyankaRajkakati.Space.

Editors' Notes: Dr. Priyanka Rajkakati is an engineer turned artist (and environmentalist). She offers not only a colorful retrospective look at the role of art in space exploration, but also a unique perspective on actual art in space—as she has sent her own art (along with others' works) to the International Space Station. She then provides a challenge for making artistic expression a bigger part of space exploration … and concludes with a deeply personal reflection, leading by example. Following Dr. Bob Krone's lead, we too advocate for a future in space that fully embraces humanity's unique capacity for artistic expression. ***Mark Wagner and Gordon Arthur*****.**

The Urgency of Space Migration

By Michael Goff

Debates rage about whether space migration is a moral good. Can human intervention in extraterrestrial environments be considered a positive thing? Is human civilization a morally positive force, and if so, is expanding it far across time and space a good thing? Within the framework of the idea that space migration, in the abstract, is a good thing, there is a debate on how high a priority space endeavors carry, and with how much urgency they should be carried out. I argue that space migration, as a moral good, should also be regarded as an urgent priority, for there is no guarantee that the window of opportunity presented to humanity today will remain open indefinitely.

The arguments for delay are manifold and, at first glance, seemingly sensible. First, there is the argument that, as there are significant terrestrial problems, effort expended on space exploration will detract from more compelling priorities. Perhaps, then, space endeavors should wait until conditions on Earth are improved. A major problem with this reasoning is that there is no reason to expect that, if NASA's or private space ventures were halted, the resources spent on these ventures would then be diverted toward a desired aim. Humanity now comprises eight billion people, leaving ample opportunity to pursue many priorities simultaneously. World government spending is over $14 trillion per year, ostensibly for public good, and it is highly doubtful that the addition of less than 1% of that for other purposes would make a decisive difference in any terrestrial outcome.

Space exploration is dangerous and physically taxing. The first generations of Martian explorers, and of permanent dwellers in orbit, on the Moon, and on Mars, will face severe risk of death from accidents, as well as threats from radiation, rudimentary medical care, zero or low gravity, psychological stress, and other risks. Perhaps after a sufficient period of time, supertechnologies such as warp drives, matter replicators, or artificial general intelligence will be available and reduce the risk. Therefore, it is morally sensible to delay further human space exploration until such technologies are developed.

Against these considerations is the overwhelming case for urgency. First, as thinkers such as Stephen Hawking have argued, an earthbound humanity faces severe existential risks, such as nuclear war or ecological disaster. If humanity has built self-sustaining civilizations in multiple places throughout the solar system, or especially in multiple places beyond the solar system, the risk of a disaster that could permanently foreclose space migration is greatly reduced.

Even absent a disaster on the magnitude of general nuclear war, delay carries risk. Those of us living in the early 21st century have experienced such extensive progress in the modern world—in science and technology, in economic growth, in peaceful and just government, in rising standards of living, and in respect for human rights and dignity—that it is tempting to take such progress for granted. But it is not automatic or inevitable that the future will continue to be better than the present.

Indeed, in the early 21st century, there are several worrying signs that this trend of progress may halt and go into reverse. Breakthrough scientific discoveries and technological inventions are becoming less common. Governments and major institutions are becoming more sclerotic and unable to address the needs of the public or the purposes for which they were created. Economic growth in wealthy countries is slowing down. Birth rates are falling worldwide to the point where most wealthy and many middle-income countries are not able to maintain their populations. The impulse to delay space migration is part of the "can't do" attitude that underlies many of these trends.

A delay in space migration, will, at best, deprive a generation of the opportunity to enjoy the scientific, technological, cultural, and spiritual fruits of such an enterprise. At worst, delay is tantamount to preventing migration from happening at all. To borrow a phrase from Alex Steffen, writing about action on climate change, the excuses offered against approaching space migration with great urgency constitute "predatory delay" and should be firmly rejected. Instead, we must approach space migration with all the care and deliberation demanded of what may be a central project. Such deliberation is the opposite of delay.

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Editors' Notes: As we near the end of this issue, we hope you leave with not only a prospective approach to space migration, but also a sense of urgency around it. As first-time contributor Dr. Michael Goff eloquently argues in this brief piece, delay could be catastrophic. It is up to each of us to do our part in communicating this urgency to others so that catastrophe can be averted in the coming decade. ***Mark Wagner and Gordon Arthur*.**

Space Philosophy: The Symmetry Hypothesis

By J. N. Nielsen

Abstract

The *terrestrial/extraterrestrial symmetry hypothesis* is introduced, according to which space travel changes nothing in respect to philosophy, implying that there is no distinctive space philosophy. Arguments for and against the symmetry hypothesis are explored, breaking down the question into the five branches of philosophy, metaphysics, epistemology, logic, aesthetics, and ethics. A possible way forward in the analysis of the symmetry hypothesis is suggested through a distinction between trivial and non-trivial philosophical ideas, such that change in trivial ideas is a merely contingent argument against the symmetry hypothesis, leaving philosophy essentially unchanged, while change in non-trivial philosophical ideas passes beyond the threshold of merely contingent change and makes space philosophy essentially different from terrestrial philosophy, in which case the symmetry hypothesis is essentially falsified. Potential directions for research into the symmetry hypothesis are suggested.

Keywords: Space philosophy, symmetry, space exploration, triviality, non-triviality, G. H. Hardy.

The Symmetry Hypothesis

Is there a justification for space philosophy as a distinct discipline? Does the fact of space travel, space exploration, and space science have any substantive bearing upon philosophical thought? Should there be a space philosophy that develops in the light of human space exploration experiences? Or, on the contrary, should philosophy recognize no distinct division of space philosophy, and should we therefore hold that space travel, space exploration, and space science have no relevance whatsoever to philosophy?

To examine these questions more closely, we formulate the *terrestrial/extraterrestrial symmetry hypothesis*, or simply the *symmetry hypothesis*, as a foil to the distinctiveness of space philosophy. The symmetry hypothesis maintains that there is a thorough-going symmetry between philosophical problems in a terrestrial context and philosophical problems in an extraterrestrial context. In short, according to the symmetry hypothesis, nothing is changed in philosophy by the advent of space travel; human life and the human condition in outer space remain philosophically symmetrical with human life and the human condition on Earth. Philosophical problems remain relevant as they were formulated prior to the advent of space travel, but nothing is added to, subtracted from, or altered within any philosophical problem, and no philosophical theory intended to resolve a philosophical problem needs to be expanded, narrowed, or altered as a result of space exploration.

If the symmetry hypothesis can be shown to be false, then space philosophy can be shown to be a distinct and justified discipline; if the symmetry hypothesis can be shown to be true, then space philosophy is no distinct discipline at all. In the latter case, we can posit a future in which philosophical research continues, and human beings who do in fact live and work in space contribute to the formulation and resolution of philosophical problems, but the fact that philosophers live and work in space is an irrelevant contingency with no bearing upon their philosophical research, so that if such contributions constitute a major advance in philosophy (or a major decline in philosophy), this advance (or this decline) is to be entirely attributed to the intellectual capacity of the individual philosophers, or to their intellectual milieu, and never to the distinctive life circumstances (i.e., extraterrestrial circumstances of living in outer space) of the individual philosopher, in contradistinction to the life circumstances of all philosophers to date, which have been exclusively terrestrial circumstances.

The symmetry hypothesis is a null hypothesis for space philosophy, and the possibility of confirming or disconfirming the symmetry hypothesis suggests in turn the possibility of a Type I error (rejection of a true null hypothesis; a false positive) or a Type II error (failure to reject a false null hypothesis; a false negative). The symmetry hypothesis incorrectly rejected would mean that space philosophy is *not* distinctive, though arguments purport to demonstrate its distinctiveness. For example, the human experience in space could be such as to disorient our abilities and falsely imply that something is changed by human experiences in outer space, e.g., by the Overview Effect,[1] when in fact nothing is changed. On the other hand, failure to reject a false symmetry hypothesis would mean that space philosophy *is* distinctive (or *ought* to be treated as a distinct discipline), though arguments purport to demonstrate its non-distinctiveness. For example, our inability explicitly to formulate a subtle and elusive difference between terrestrial experience and extraterrestrial experience (or between knowledge derived from terrestrial experience and knowledge acquired from extraterrestrial experience) could falsely imply that nothing is changed when in fact there is a change, but we are not capable of explicitly formulating or measurably quantifying that change.

Arguments For and Against

Perhaps the most obvious argument in favor of the symmetry thesis is the conception of the universe adopted in contemporary science, obtained by rejecting a two-tier universe in which conditions and laws are fundamentally different on Earth and in space. In Ptolemaic cosmology and its medieval elaborations, below the sphere of the Moon, the sublunary world operates according to one set of laws (objects move in straight lines and seek their lowest level), while above the sphere of the Moon, the

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[1] Frank White, *The Overview Effect: Space Exploration and Human Evolution* (Boston: Houghton Mifflin, 1987).

superlunary world operates according to a different set of laws (objects move in circles and remain within their proper heavenly sphere).

If the cosmological principle is understood to entail that space is both homogeneous and isotropic, then spatial phenomena ought to be the same here (on Earth's surface) as there (in outer space), and it is the implicit adoption of the cosmological principle with the advent of the scientific revolution that is the death knell of Ptolemaic cosmology and the nativity of Copernican cosmology.

Experimentation in empirical science recognizes several symmetries—e.g., symmetry in space, symmetry in time—however, symmetry of scale generally fails to obtain.[2] An experimental apparatus constructed an order of magnitude larger, or an order of magnitude smaller, than the apparatus of a canonical experiment may not produce the same observational outcomes as the canonical experiment.[3] The microscopic world must sometimes be explained according to different scientific theories than those that explain the macroscopic world, and vice versa. Yet an experiment performed in the Milky Way galaxy should give the same result as the same experiment performed in the Andromeda galaxy (translation in space), and an experiment performed today should give the same result as the same experiment performed a thousand years from now (translation in time).

What symmetries obtain, or fail to obtain, in philosophical ideas? Taking the traditional five branches of philosophy as the basis for the subdivision of the discipline, the symmetry hypothesis can be narrowed to more specific parameters, analogous to the symmetry parameters of space, time, acceleration, and scale in empirical science:

> *Metaphysical asymmetry* obtains when metaphysical formulations (metaphysical problems and theories) of terrestrial philosophy do not coincide with metaphysical formulations of extraterrestrial philosophy.
>
> *Epistemological asymmetry* obtains when epistemological formulations of terrestrial philosophy do not coincide with epistemological formulations of extraterrestrial philosophy.
>
> *Logical asymmetry* obtains when logical formulations of terrestrial philosophy do not coincide with the logical formulations of extraterrestrial philosophy.

[2] Richard Feynman, *The Character of Physical Law* (Cambridge, MA: MIT Press, 1985).

[3] Further elaboration of the scientific conception of symmetry can be found in Hermann Weyl, *Symmetry* (Princeton, NJ: Princeton University Press, 1952) and Eugene P. Wigner, *Symmetries and Reflections: Scientific Essays of Eugene P. Wigner* (Bloomington: Indiana University Press, 1967).

Aesthetic asymmetry obtains with aesthetic formulations of terrestrial philosophy do not coincide with the aesthetic formulations of extraterrestrial philosophy.

Ethical asymmetry obtains when ethical formulations of terrestrial philosophy do not coincide with the ethical formulations of extraterrestrial philosophy.

In each case of the above permutations, symmetry is obtained when formulations of terrestrial and extraterrestrial philosophy precisely coincide, and asymmetry when they fail to coincide. In the former case, terrestrial philosophy can be taken whole and be applied unchanged to human life in outer space, and this displaced philosophy remains equally valid and relevant (or equally irrelevant) to human life, notwithstanding the changed context. Let us now frame some arguments for each of these symmetries:

Metaphysical symmetry argument: no terrestrial being placed in extraterrestrial space alters the metaphysical structure or cognition of the world—it does not rearrange the furniture of the world, adding to, subtracting from, or altering that ultimate furniture, nor does it add to, subtract from, or alter the joints at which nature is to be carved—but the spatial placement of actually existing objects is a paradigm of a contingent property with no metaphysical significance.

Epistemic symmetry argument: the same conditions that would be the ground of distinctive human experiences in outer space, from which distinctive forms of knowledge might be framed, are grounds upon which we should reject this experience as not being normative of the human condition, and therefore an insufficient ground for the formulation of novel knowledge.

Logical symmetry argument: following the epistemic symmetry argument above, if we ought to reject non-normative epistemic claims following from human experience in space, no novel forms of reasoning are called forth by novel forms of knowledge; knowledge remains invariant despite space exploration. Therefore, logic remains invariant with respect to human knowledge, even in light of space exploration.

Aesthetic symmetry argument: while novel experiences of natural beauty may follow from space exploration, we could only find these experiences beautiful (or ugly) on the basis of principles and judgments that are identical to our aesthetic principles and judgments in a terrestrial context. Without these invariant principles and judgments, we would not be able to judge any of the natural beauties afforded by space exploration as beautiful (or ugly). Therefore, any claim of novel forms of beauty requiring novel aesthetic principles or judgments is self-defeating.

Ethical symmetry argument: parallel to the argument for aesthetics, any novel moral experiences that follow from space exploration could only be judged to be moral experiences on the basis of invariant moral principles and judgments derived from our terrestrial experience. Without these invariant moral principles and judgments, we would be unable to identify these novel experiences as being moral (or immoral). Therefore, any claim of novel forms of moral experience requiring novel moral principles or judgments is self-defeating.

If any of the above arguments are valid, the symmetry hypothesis is true in regard to that branch of philosophy. If any of the above arguments are invalid, the null hypothesis, here the symmetry hypothesis, is false, but we have taken it to be true on the basis of an invalid argument, which is then a false negative, constituting a Type II error.

Let us also frame a possible form of asymmetry for each of the above permutations:

Metaphysical asymmetry argument: insofar as human being is a form of being *simpliciter*, the presence of human being in outer space is a distinct metaphysical state-of-affairs that does not obtain in the absence of space travel. Therefore, space travel results in a novel metaphysical state of affairs, which can be formulated as a novel metaphysical theory.

Epistemic asymmetry argument: distinctive human experiences in outer space, such as the experience of zero gravity and microgravity, and the experience of the Overview Effect, are novel empirical states-of-affairs that can be formulated as human knowledge. Therefore, space travel results in novel epistemological outcomes.

Logical asymmetry argument: distinctive human experiences in outer space require novel forms of reasoning to be assimilated to the extant body of scientific knowledge. Therefore, space travel necessarily results in the introduction of novel principles of reasoning, and novel applications of existing principles of reasoning.

Aesthetic asymmetry argument: distinctive human aesthetic experiences in outer space expand the scope of the appreciation of natural beauty. Eventually, human works of art created in outer space will analogously expand the scope of artistic beauty. An expansion in the scope of aesthetics through the expansion of the possibilities of natural and artistic

> beauty constitutes a qualitative change in the context of aesthetic principles and judgments, requiring novel interpretations of traditional aesthetic principles and judgments, or the introduction of new aesthetic principles and judgments.
>
> *Ethical asymmetry argument*: parallel to the argument for aesthetics, distinctive human moral experiences in outer space expand the scope of human moral action. An expansion in the scope of moral action through the expansion of the possibilities of human action in outer space constitutes a qualitative change in the context of moral principles and judgments, requiring novel interpretations of traditional moral principles and judgments, or the introduction of new moral principles and judgments.

If any of the above arguments are valid, the symmetry hypothesis is false, at least in part. If, on the contrary, any of the above arguments are invalid, terrestrial/extraterrestrial symmetry obtains, at least in part. In this latter case, the null hypothesis, here the symmetry hypothesis, is true and we have rejected it (if only in part) on the basis of an invalid argument, which here constitutes a Type I error.

The arguments formulated above are not to be taken as definitive or exhaustive; the failure of any one argument does not demonstrate the indefensibility of a given aspect of symmetry or asymmetry, as other arguments could be adduced. These arguments are presented only as exhibits to illustrate some dimensions of the symmetry hypothesis, as narrowed to traditional branches of philosophy. This narrowed scope is intended to sharpen our focus on possible areas of asymmetry between terrestrial and extraterrestrial human experience, and the formalization of that experience in human knowledge.

While further elaboration of these arguments might afford an exploration of the problem posed by the symmetry hypothesis in greater detail, and a more detailed and comprehensive analysis might be necessary to map the precise symmetries and asymmetries between human terrestrial and extraterrestrial experience exhaustively (or to demonstrate an exhaustive symmetry that proves the symmetry hypothesis), none of these arguments appears definitive, and nor does a definitive argument present itself *prima facie* along with the formation of the problem of the symmetry hypothesis. One approach to the clarification of the symmetry hypothesis, and thus its confirmation or disconfirmation, may come about from just such an effort toward an exhaustive mapping. However, another approach may be possible.

A Possible Way Forward

Metaphysics has always sought a purely symmetrical account of the world, in the sense that a metaphysical theory ought to be invariant with respect to mere contingencies, or even with respect to the "trivial and undignified objects" lacking the Forms that Plato has Socrates enumerate in the *Parmenides*,[4] including hair, mud, and dirt.[5] This metaphysical imperative to transcend the contingent and the trivial is complementary to the metaphysical pursuit of perfect generality and foundational depth in its formulations, which would seem to exclude the contingent and the trivial. An account of non-trivial philosophical ideas may provide a way forward in clarifying exactly what is at issue with the symmetry hypothesis.

While a precise or formal distinction between trivial and non-trivial philosophical ideas, presumably based on trivial and non-trivial experience, will probably elude us, we can appeal to an intuitive conception of non-triviality proposed by G. H. Hardy in *A Mathematician's Apology*[6] to distinguish trivial from non-trivial mathematics. Hardy considered trivial mathematics to be "repulsively ugly and intolerably dull,"[7] but he did not stop at noting the "permanent aesthetic value"[8] of non-trivial mathematics. For Hardy, pure mathematics consists of serious theorems that contain significant ideas. Significant mathematical ideas are characterized by generality and depth.[9]

Generality is further explicated in terms of being "a constituent in many mathematical constructs," and "used in the proof of theorems of many different kinds."[10] Moreover, "The relations revealed by the proof should be such as connect many different mathematical ideas."[11] Of depth Hardy says, "mathematical ideas are arranged somehow in strata, the ideas in which stratum being linked by a complex of relations both among themselves and with those above and below. The lower the stratum, the deeper (and in general the more difficult) the idea."[12] Hardy also notes that the most beautiful theorems of pure mathematics exhibit "*unexpectedness*, combined with *inevitability* and *economy*."[13] The properties of unexpectedness, inevitability, and economy, however, are not given an (informal) exposition in his *Apology* as are the ideas of generality and depth.

The unexpected, we can observe, derives from fundamental connections not explicit at a superficial level, but which manifest themselves at a deeper level. For all practical purposes, this is the metaphysical distinction between appearance and reality. Hardy is

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[4] Plato, *The Collected Dialogues of Plato, Including the Letters*, ed. Edith Hamilton and Huntington Cairns (Princeton, NJ: Princeton University Press, 1985).
[5] Plato, *Collected Dialogues*, 924.
[6] G. H. Hardy, *A Mathematician's Apology*, foreword by C. P. Snow (New York: Cambridge University Press, 1976).
[7] Hardy, *A Mathematician's Apology*, 140.
[8] Hardy, *A Mathematician's Apology*, 131.
[9] Hardy, *A Mathematician's Apology*, 103.
[10] Hardy, *A Mathematician's Apology*, 104.
[11] Hardy, *A Mathematician's Apology*, 104.
[12] Hardy, *A Mathematician's Apology*, 110.
[13] Hardy, *A Mathematician's Apology*, 113.

thus suggesting that trivial mathematics is the mathematics of appearances, while non-trivial mathematics is the mathematics of reality. Analogously, trivial philosophy can be understood as the philosophy of appearances, while non-trivial philosophy is the philosophy of reality, and it is metaphysical by definition. Reality (and any metaphysical account of reality) is here understood to be symmetrical with respect to all appearances, and thus invariant in respect to trivial matters.

Translating Hardy's conception of non-trivial mathematics into a conception of non-trivial philosophy is straightforward at this point: significant philosophical ideas are characterized by generality and depth, and the most beautiful philosophical ideas exhibit unexpectedness, inevitability, and economy. (One property that Hardy notably did *not* note as characterizing significant ideas is that of *simplicity*, but we will observe that simple ideas are often fundamental ideas, and that they often exhibit the properties that Hardy ascribed to the lowest stratum of ideas; a connection between the fundamental and the simple is assumed below.)

We may compare Hardy's conception of depth to Gödel's attempts throughout his later life to penetrate the principles that underlie the axioms of set theory. From a formal point of view, the axioms of set theory are foundational, but we know that there are many different axiom systems that can be adopted for the exposition and development of set theory. This implies that there are deeper principles that are the manifested in all axiom systems of set theory, and it is from these deeper principles—the *reality* of set theory, rather than its mere appearance—that we derive the common understanding of all these axiom systems as all being concerned with set theory.

Gödel, like Hardy, struggled with formulating adequate intuitive conceptions of formal ideas. (In mathematics, as in logic, and indeed in philosophy, there is always a tension between intuition and formalization.) Gödel appealed to the works of Leibniz and Husserl in his attempts to clarify fundamental ideas in formal thought. Hao Wang recounts Gödel's efforts formulate the underlying principles of set theory in *From Mathematics to Philosophy*[14] and *A Logical Journey*.[15] With Gödel and Hardy's attempt to elucidate the most fundamental stratum of mathematics, one is reminded of Kierkegaard's observation in his *Concluding Unscientific Postscript* of the relation of the wise man to simplicity:

> When a servant-girl weds a day-laborer everything passes off quietly, but when a king weds a princess it becomes an event.... It is thus that the wise

[14] Hao Wang, *From Mathematics to Philosophy* (London: Routledge & Kegan Paul, 1974), 189–90.
[15] Hao Wang, *A Logical Journey: From Gödel to Philosophy* (Cambridge, MA: MIT Press, 1996), 280–81.

> man is related to the simple. The more the wise man thinks about the simple … the more difficult it becomes for him.[16]

Significant mathematical ideas and significant philosophical ideas share this character: the more we think of them, the more difficult they become. Significant philosophical ideas mark the work of philosophers whose ideas have been passed down to us by tradition: Plato, Aristotle, Descartes, Hume, Kant, and so on. We readily recognize them even if we cannot adequately define them.

Given the metaphysical imperative to pursue non-trivial formulations of generality and depth that exhibit unexpectedness, inevitability, and economy, the question for space philosophy is whether the translation of a philosophical problem from terrestrial circumstances to extraterrestrial circumstances fulfills or frustrates this metaphysical imperative. If human experience in space, and human knowledge formulated on the basis of this extraterrestrial experience, is unexpected, inevitable, and economical, then human experience in outer space is non-trivial, and its formulation as knowledge may be assumed to issue in greater epistemic generality and depth.

We have reason to believe that this is the case, in the same way that astrobiology is providing distinctive insights into biology, which, to date, as been terrestrial biology, but which is now being formulated in a cosmological context in astrobiology. Thus also human experience, once exclusively terrestrial experience, is now being formulated in a cosmological context, both as a result of the growth of scientific knowledge, that places human beings within the cosmos scientifically understood, and as a result of space exploration, which provides a perspective on the cosmos that is not available to terrestrial experience. These conditions provide distinctive insights into human experience, which, to date, has been a terrestrial experience, but which is now being expanded to incorporate extraterrestrial experience.

Once an astronaut has been launched into outer space, the acquisition of the perspective of outer space in *inevitable* (barring trivial objections such as the possibility of an accident upon launch); at least some aspects of the experience of space flight are *unexpected* (despite extensive training and preparation); how parsimony ought to be understood in this context is not immediately obvious, but insofar as human experience in outer space requires no special accommodation to be distinctive from terrestrial human experience, and is therefore *unexpected*, it can be identified as *economical*. From this unexpected, inevitable, and economical experience of outer space, its eventual formulation as human knowledge suggests greater generality and depth as human experience is enlarged in scope and scale, though the full realization of this promise will only come in the fullness of time.

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[16] Søren Kierkegaard, *Kierkegaard's Concluding Unscientific Postscript*, trans. David F. Swenson, completed by Walter Lowrie (Princeton, NJ: Princeton University Press, 1944), 143.

The Utility of the Symmetry Hypothesis

The symmetry hypothesis can be employed to probe for essential novelty in any philosophical domain related to space travel. In considering apparently new questions in philosophy of technology, philosophy of history, or philosophy of religion, *inter alia*, which may appear to be posed for the first time by the intersection of space exploration with technology, with history, or with religion, *inter alia*, we can pose the question in terms of the symmetry hypothesis in an attempt to determine from the outset whether the novelty of the question is as it appears to be.

The utility of the symmetry hypothesis is not limited to probing the philosophical possibilities of space exploration. In some respects, human life has changed very little or not at all since the speciation of *Homo sapiens* (or even before), while in other respects the human condition has changed beyond measure, and with each disruptive change to the human condition we can pose the symmetry hypothesis anew. Does any philosophical novelty result from the Neolithic Agricultural Revolution? The Industrial Revolution? The internet? Artificial intelligence?

The symmetry hypothesis recommends itself—and, in recommending itself, exhibits a kind of symmetry across disciplines—as a way to examine apparent novelty in human experience philosophically. When any new technology presents human beings with apparently novel philosophical questions, we can ask of that new technology whether it raises philosophical questions that are asymmetrical with respect to the philosophical tradition to date. Thus, with the many ethical dilemmas posed by novel biotechnologies—reproductive technology, gene editing, longevity, etc.—we can ask whether the *status quo ante* exhibits a symmetry with human life after the introduction of the technological innovation in question.

In part, the extrapolation of the symmetry hypothesis to technological changes in human life other than space exploration constitutes a thesis in the philosophy of technology, but it is possible to formulate a version of the symmetry hypothesis that is not due to technology: suppose that some mutation occurs in a human population that causes a bifurcation of humanity into two or more species. Two forms of humanity, two species of human beings (i.e., two species of the genus *Homo*), are the result, each capable of speech and reason. Each can ask itself whether the human condition before the speciation event was philosophically symmetrical with the human condition(s) after the speciation event. With human speciation merely postulated in this way, and without any biological details on a future human speciation, it cannot be said whether the symmetry thesis obtains or fails to obtain, and whether it does may depend upon the particular nature of any changes that attend a given human speciation event.

A Final Reflexive Observation

Looking at the symmetry hypothesis reflexively, we can see that, as formulated in terms of terrestrial/extraterrestrial symmetry, it is a distinctive problem of space philosophy, and it seems to be non-trivial insofar as it is not easily dismissed (or non-trivially affirmed); i.e., it is neither intuitively nor *prima facie* true or false. If the symmetry hypothesis itself is non-trivial, then it demonstrates that at least one philosophical problem distinctive to space philosophy is non-trivial, which means that some part of space philosophy is a distinctive and justified discipline.

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Editors' Notes: Returning to the *Journal of Space Philosophy* for the second time, independent scholar J. N. "Nick" Nielsen poses an existential challenge, suggesting that perhaps there is no such field as space philosophy after all—and thus that the continued publication of this journal might not be justified. In true academic fashion, Nielsen proceeds to argue multiple sides of the debate, before offering a way forward. Thankfully he concludes that our pursuits are non-trivial and provides a worthy addition to the literature … and an exciting conclusion to this landmark issue of the JSP. ***Mark Wagner and Gordon Arthur*****.**