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?

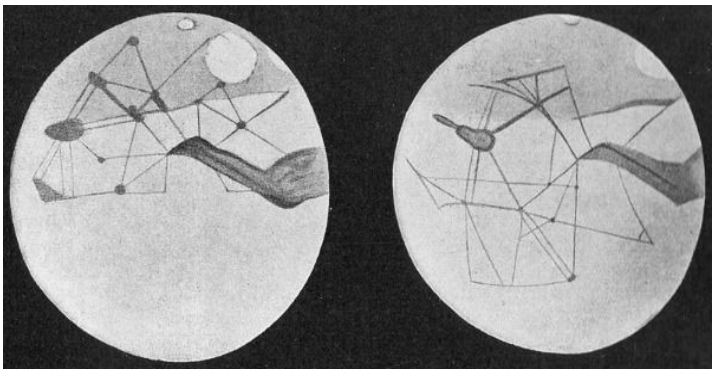
In this period of modern-day rocketry, spacecraft designs can even be traced back to ideas proposed by science fiction authors, such as Jules Verne, who wrote *From the Earth to the Moon* in 1865. There is also evidence to suggest that spaceflight pioneers such as

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

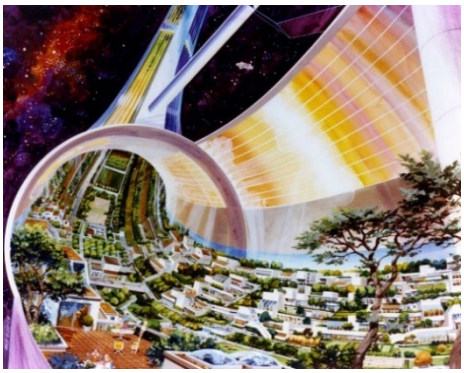
Konstantin Tsiolkovsky, Hermann Oberth, and Robert Goddard were quite influenced by speculative novels published in Russia, Germany, and the United States in the nineteenth century.[4] Even the dream of living on Mars has existed since at least the end of the nineteenth century, with H. G. Wells's 1897 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).

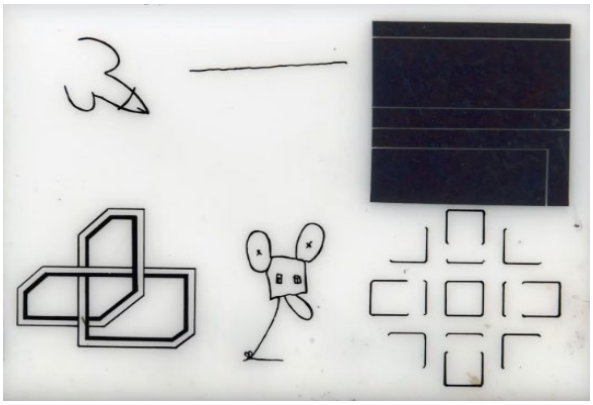
[5] www.businessinsider.com/cremated-ashes-pluto-space-probe-2018-10.

[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

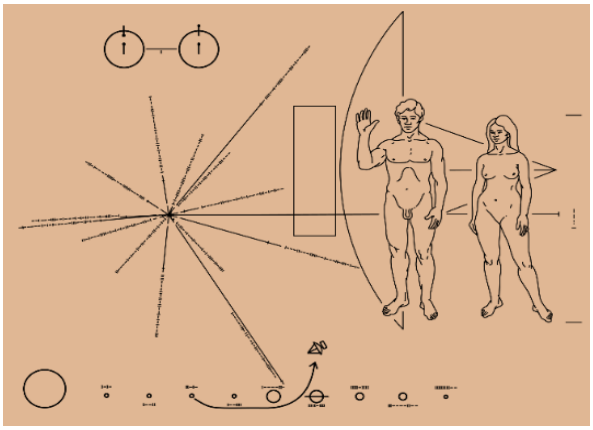
So far, we have seen not only how the vast cosmos has inspired artistic expression, but also how art has in turn inspired actual technological advancements. However, the concept of space art would be incomplete without including works that have actually gone into space, crossing the Karman line of 100 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)

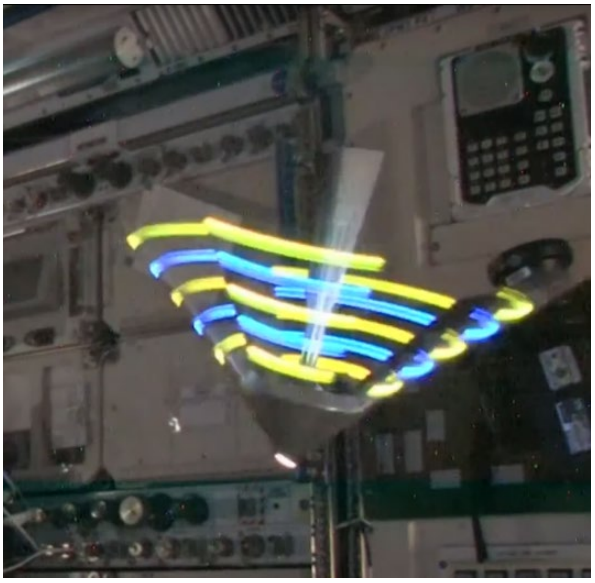
Voyager Golden Records (1977)

[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).

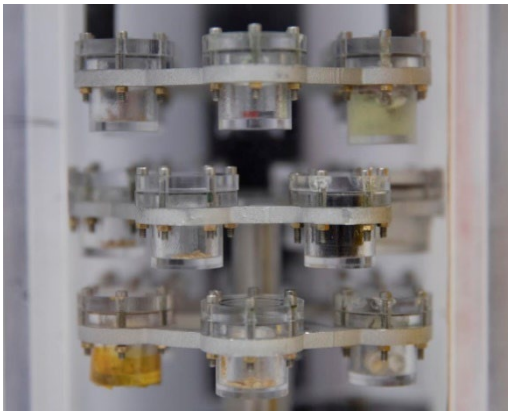
worldwide quilting project while sewing in the ISS. Continuing the tradition, current NASA astronaut candidate, Zena Cardman, is an Antarctic adventurer as well as a trained poet.

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.

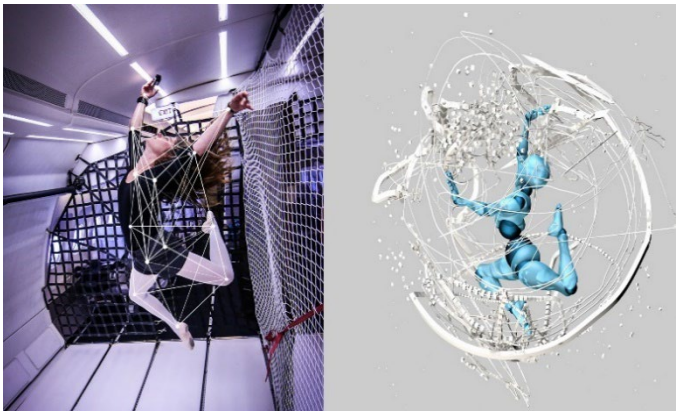
When it comes to music and poetry, Maya Angelou's poem, *A Brave and Startling Truth* was flown on the NASA Orion spacecraft during its first flight in 2014. French designer, Nelly Ben Hayoun, created the International Space Orchestra, composed of famous musicians, scientists, and astronauts, and which 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

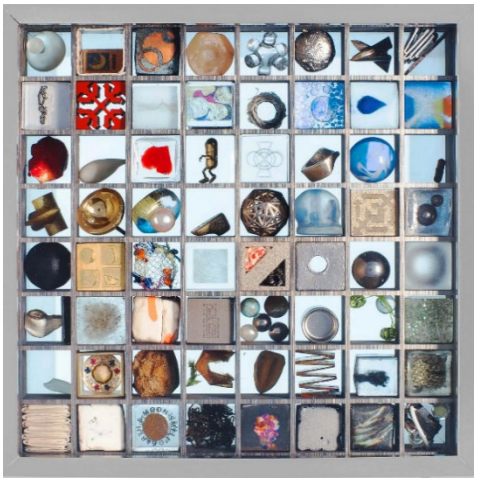
Sarah Jane Pell ("aquabatics"). Finally, Peggy Hollinger, not an artist but the International Business Editor at the *Financial Times*, collaborated with graphics journalist Sam Learner to write an engaging piece called *How Space Debris Threatens Modern Life*, which is a piece of art in itself, showing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

---

[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.

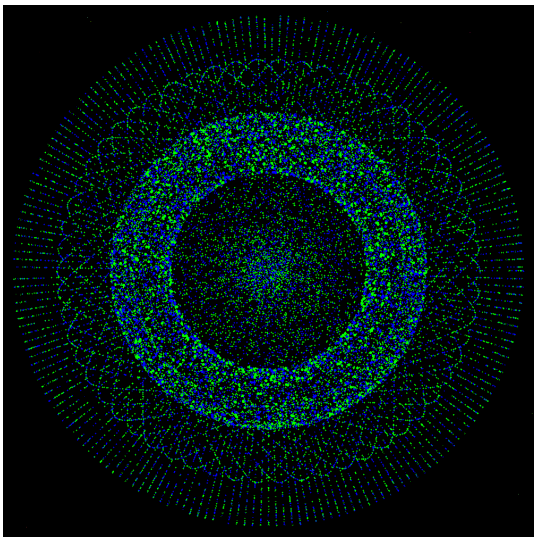
Therefore, we need some space for art in space.

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 $h = b$.

****

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.***