SPACE ART + SPACE SCIENCE
A polymathic paradigm shift in the art/science dialogue

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Abstract

Perhaps no other field of scientific endeavor has been more influenced by the arts than space exploration. The artistic visions of yesteryear are the technological realities of today. These realities in turn create new possibilities for artistic expression. However, Space Art and Space Science have shared a convoluted history. Their forerunner disciplines of the Humanities and Natural Sciences and their practitioners were entrenched as polar opposites for centuries. Recent research, however, has revealed the reverse; that the psychological profile and the creative processes of artists and scientists are actually similar, often to the point of the practitioners being polymathic. Moreover, it has been discovered that polymathic ability nurtures two qualities essential for the survival of both Space Art and Space Science: that of creativity and innovation.

Current literature has taken note of the commonality of polymathic ability between the practitioners of the arts and sciences. Academic and industry think tanks have examined the virtues of artists as space researchers, and conversely, scientists developing an artistic approach as a design strategy. Thought leaders have expressed faith in trans-disciplinary collaboration as the way forward in the global affairs of space. Yet, therein lies the problem. These various studies individually lack a cohesive strategy to leverage their findings and transform the Art/Sci dialogue into a disruptive force that sustains a paradigm shift in the arts, space and society agendas going forward.

The impetus for this dissertation is the unique opportunity to amalgamate those disparate studies by utilizing the momentum of New Space culture, and its focus on societal inclusion and environmental concerns to serve as anchors for space research and sustainability. Further, we argue that the next logical step is to inculcate a fundamental Art/Sci paradigm shift within the space community to exploit the unprecedented global drive towards space exploration and colonization, thereby solidifying the influence of the space art and space science agendas in the service of the global commons on Earth and in space.

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Dedicated to those artists, scientists and polymaths over the centuries who kept the fascination of interacting with space alive and well.

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List of Acronyms

3D	3 Dimensional
AISES	American Indian Science and Engineering Society
ART/SAT	Art Satellite
ASKAP	Australian Square Kilometre Array Pathfinder
BA	Bachelor of Arts
BIS	British Interplanetary Society
CalTech	California Institute of Technology
CERN	European Organization for Nuclear Research
CERT	Council of Energy Resource Tribes
CICLOPS	Cassini Imaging Central Laboratory for Operations
CMU	Carnegie Mellon University
COPUOS	Committee on the Peaceful Uses of Outer Space
COSMOS	Cosmic Evolution Survey
DESPATCH	Deep Space Amateur Troubadour's Challenge
DIY	Do It Yourself
EFF	Electronic Frontier Foundation
ESA	European Space Agency
ESR	Earth Situation Room
ETTAS	European Space Agency's Topical Team for Arts and Sciences
ETTO	ESA Technology Transfer Office
FCC	Federal Communications Commission
IAAA	International Association of Astronomical Artists
IAF	International Astronautical Federation

IMDb	Internet Movie Database
INVADER	INteractiVe satellite for Art and Design Experimental Research
ISAST	International Society for the Arts, Sciences and Technology
ISS	International Space Station
ITACCUS	IAF Technical Activities Committee for the Cultural Utilisation of Space
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
LED	Light Emitting Diode
MFA	Master of Fine Arts
MIT	Massachusetts Institute of Technology
NAACP	National Association for the Advancement of Colored People
NASA	National Aeronautics and Space Administration
NCREST	National Center for Restructuring Education, Schools & Teaching
NGO	Non Governmental Organization
NSF	National Science Foundation
NOAA	National Oceanographic and Atmospheric Administration
OSIRIS-REx	Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer
RISD	Rhode Island School of Design
ROSCOSMOS	Roscosmos State Corporation for Space Activities
SDGs	Sustainable Development Goals
SKA	Square Kilometer Array
STEAM	Science, Technology, Engineering, Art and Mathematics
STEM	Science, Technology, Engineering and Mathematics
UN	United Nations
UNESCO	United Nations Education, Scientific and Cultural Organization
US	United States
USGS	US Geological Survey
USSR	Union of Soviet Socialist Republics
WWII	World War II

Chapter 1

Introduction

1.1 Introduction

The phenomena of the universe provide the basis of the interrelationship between Space Art and Space Science, as both disciplines strive to observe and express the mysteries of the cosmos. Historically the relationship was tumultuous. In Western culture the arts were categorized under the Humanities, and the nascent sciences were categorized under the Natural Sciences. With time, the disciplines became entrenched in a cultural paradigm that branded them and their practitioners as polar opposites: Art as a function of the right hemisphere of the brain, qualitative, with artists passionate and chaotic; Science as a function of the left brain, quantitative, and scientists as cold and impassive.

Although this entrenched paradigm dictated the relationship of the arts and sciences up until the 20^{th} century, space artists and space scientists then as now continue to share one common trait: an ardent fascination with what is in space, what goes on in space, and how that might relate to their day-to-day lives on Earth. Artists and scientists, two groups who conceive space and how to live in it, do not work in a vacuum. To a lesser or larger degree each is influenced by and reliant upon the inspiration and the ideas of the other. Fortuitously, the dawn of the Space Age irrevocably altered the Art/Science paradigm by creating a bridge over this divide via transdisciplinary collaboration.

Current data also contradict the historic dichotomy and reveal that artists and scientists are not stereotypical opposites, but rather, as being extraordinarily similar in their aesthetics, psychological profiles and creative processes. Statistics compiled and contextualized by Robert and Michèle Root-Bernstein indicate that overlapping polymathic ability in both the arts and sciences is instrumental in nurturing creativity and innovation, two essential qualities necessary for both meaningful artistic expression and scientific endeavor (Root-Bernstein, 2008). One can extrapolate, therefore, that creativity and innovation also drive the space industry.

Perhaps no other field of scientific endeavor has been more influenced by the arts than space exploration. The artistic visions of yesteryear are the technological realities of today. These technological realities in turn create new possibilities for artistic expression. Thus, the creative nexus between the two has never been as invigorating as in the present or as replete with possibility.

Recent literature has taken note of the legacy of polymathic ability between practitioners of the arts and sciences. Academic and industry think tanks have examined the virtues of artists as space researchers, and conversely, scientists expanding their capacity in the arts as a design strategy. Thought leaders have expressed faith that transdisciplinary collaboration is the way forward in the global affairs of space, but none of these concepts are as widely accepted as needs be by the majority of decision making actors in the space community. Therein lies the problem: these various studies individually lack a cohesive strategy to leverage their findings into a concerted platform from which to transform the Art/Sci dialogue into a leading disruptive force in the arts, space and society agendas.

This dissertation puts forward the argument that the space arena itself is undergoing a period of transformation with the emergence of what is being referred to as the New Space movement that has greatly lowered the barriers to entry for practitioners from other disciplines who wish to participate in space activities. This emergent circumstance also creates a unique opportunity to amalgamate those disparate Art/Science studies by utilizing the momentum of New Space culture, of Science, Technology, Engineering, Art and Mathematics (STEAM) education, a Space Art governance strategy, and the focus on societal inclusion and environmental concerns to serve as anchors for space research and sustainability.

The methodology employed indicative reasoning to determine if the core idea of a polymathic shift between the Arts/Science dialogue was possible or desirable. Peer reviewed research and empirical knowledge were used to confirm or invalidate whether each of the elements in the disciplines would be robust enough to support a paradigm shift in the agenda in space going forward. This inquiry examines diverse strands of thought from the disciplines of art, science, and the humanities to assess their potential as viable links in the nexus necessary to sustain a paradigm shift within the Space Art/Space Science communities.

This shift would utilize polymathic ability and transdisciplinary collaboration and exploit the current global drive towards space exploration to solidify the Sci/Art agendas into the global commons on Earth and in space. The outcome of this research indicates that the transdisciplinary nature of Space Art and Space Science to become agents of change and have significant influence going forward into Space 4.0 is not only possible, it is critical today, as we stand on the precipice of deep space exploration and the colonization of planets.

1.2 Structure of the Dissertation

The remainder of this dissertation is structured as follows:

Chapter 2: "When Art *was* Science" reflects the relationship between the ancient artists and astronomers and the development of their fields. This chapter explores the polymathic legacy of the Arts and Sciences, draws attention to myths and stereotypes, and exposes their common ground.

Chapter 3: "The Endless Horizons of Space Art" presents a historic sketch of astronomical and astronautical art through the work of six instrumental artist/scientists, illustrates the purpose and the role of artists in space exploration, illustrates the categories of space art, and describes their functions.

Chapter 4: "The Art/Sci Phenomena" presents polymathic artists who are also scientists, inventors and engineers; and the reverse, astronauts who were artists before they flew, and those who became artists after having experienced the Overview Effect of viewing the Earth from space.

Chapter 5: "Towards a Culture of Transdisciplinary Collaboration" investigates collaboration between art and science researchers, evaluates the integration of space science into the media arts, highlights how the space community strategizes Art/Sci collaborations, and expands the parameters of Space Art itself.

Chapter 6: "Space Art in The Global Commons and in Global Education" references space art, explores models of governance, ethics, conservation, and curatorial expertise regarding art created for space. It also explores the new space philanthropy, a global academic art/space platform, and the STEAM curriculum as agents of sustainable global change.

Chapter 7: "Conclusion" provides a brief synopsis of the issues at hand and addresses the big question permeating this dissertation: will an Art/Sci paradigm shift take advantage of the current global drive towards space exploration and have significant influence going forward in the next evolution of the space industry?

This dissertation is transdisciplinary and as such, required a hybrid theoretical/conceptual framework. Although the question that formulated the inquiry was predetermined, the narrative, sustained by expert opinion and intuition, developed organically. The specific aspects that advance the framework were chosen as a reflection of which specific elements of the polymathic phenomena, new space culture's transdisciplinary collaboration, and governance of art in the global commons could or should be harnessed to sustain a paradigm shift. The conclusions were formulated from a combination of detailed analysis of the literature in the field, and of empirical experience.

This dissertation is written as a qualitative inquiry. Its desktop research arena encompasses a sampling of information and opinions from the space arts and space science disciplines. It is sourced from a wide variety of informational platforms that serve academicians, scientists, engineers, artists and the general public: artworks, film, conference papers, peer review journals, books, photographs, blogs, vlogs and video presentations.

Although the mysteries of the cosmos have inspired artists in all forms of expression, visual arts, graphic arts, literary arts, musical and performing arts, in this inquiry the artwork is specifically limited to visual, plastic, illustration and media. Within the limited time and scope of this dissertation, and given the vastness of the subject, this investigation uses examples primarily from Western culture, although a few illustrative examples from other cultures have been included. Future work could build on the present dissertation to examine the space art and space science relationship from the perspective of other global civilizations, which will substantially alter, inform, and energize the historical body of knowledge in both disciplines.

CHAPTER 2

WHEN ART *was* SCIENCE

2.1 The First Space Artists

Although the term "Space Art" describes a modern genre, the term "Space Artist" itself could be applied to our earliest ancestors. Evidence unearthed in 2011 reveals that artists have been producing artworks since the dawn of human history. One hundred thousand years ago artists left behind their abalone shell paint grinding equipment and compound mixtures of pigment in the Blombos Cave near Cape Town, South Africa (see Fig. 2.1). Along with it, hidden under layers of sand dune, were ochre shards etched with abstract designs, bone paintbrushes and quartzite grinding stones (Pappas, 2011).

Archaeologists dated the abalone shell containers and their pigments as 100,000 years of age, the oldest found thus far, which predates earlier finds by 40,000 years. This find is the first known instance of a deliberate mix of various mineral oxides with binders and curative liquids, and as such, dates artists as the earliest users of elementary chemistry (Sample, 2018).

The innate drive of artists to practice art was born of human beings' desire to express what they saw and felt, and are also the earliest records of art reflecting space. Among the images are scenes recording cultural events, natural sciences, fantastical beings and the celestial phenomenon of the skies. Art in the form of painting and sculpture is the earliest attempt at

Figure 2.1: An abalone shell found in the Blombos Cave in South Africa, circa 100,000 BCE, was used as bowl to hold a red ochre paint-like substance. This is the oldest example of humans making complex substances, and of humans using containers (Henshilwood et al., 2011).

a physical rendering of the meaning of the abstract: the relationship between humans and their place in the universe.

Visual artist and MIT engineering graduate Robert E. Mueller suggests that cave artists discovered spirits in the stars and invented gods to help control their physical and metaphysical worlds. Further, that paintings recording celestial bodies and events were completed in the hopes of affecting change and foretelling the future in order to manifest some semblance of control over their destiny (Mueller, 1967).

"Art was the early human's total science. He concretized supernatural powers through an artistic attitude, helping himself to cope with the realities which they simultaneously embodied and explained"
- Robert Mueller (Mueller, 1967)

Artists were esteemed community members. Their art, infused with mysticism, was their magic, and their magic was the science of the age. In ancient times magic, religion, mysticism and philosophy were all merged and became the platform from which natural science and all other subsequent scientific disciplines expanded (Violatti, 2014).

Figure 2.2: The Lunar Maps of Knowth showing: (Left) The naked eye map; (Centre) the superimposed image; (Right) the carving from Knowth center circa 2800 BCE. These are the earliest known depictions of the Moon and its features (Stooke, 1994).

Concurrent with the development of natural sciences from Babylonia, Egypt, Greece, India, China, Meso-America and the Middle East, painters and sculptors capitalized on technological inventions and applied them to their craft. Artists took advantage of the depth that the geometry of perspective afforded their paintings, the inventions of bronze casting to create bigger, stronger sculptures, the printing press to transmit their ideas, and oil paints to expand their range of color and durability (Mueller, 1967).

In the European Renaissance period, (14^{th}-17^{th} centuries) the arts, music, literature, philosophy and the science of natural exploration were discussed with fervor and passion. The term "Renaissance Person" described an individual who was a thought leader of the times, a master of several if not all of the areas of known knowledge in the arts, humanities and natural sciences. This is where the art of polymathic engagement came into play.

2.1.1 Leonardo da Vinci

"Art is the queen of science, communicating knowledge to all the generations of the world"
- Leonardo da Vinci (Maeda, 2013)

One such universally recognized person who epitomized this polymathic era was Leonardo da Vinci. Painter, sculptor, architect, lyrist, mathematician, engineer, mentor and scientist. To Leonardo, art and science were one, and thus painting was a science. His natural ability to produce artwork was refined by single-minded study and systematic practice, his own version of the scientific method (Roche et al., 2018). He possessed the ability to imagine space and how machines would operate in it. He drew the Moon without the aid of a telescope, attempted to ascertain the orbits of the Sun, Moon, and Earth, and invented the idea of the helicopter, submarine, airplane wings, tanks, and robots.

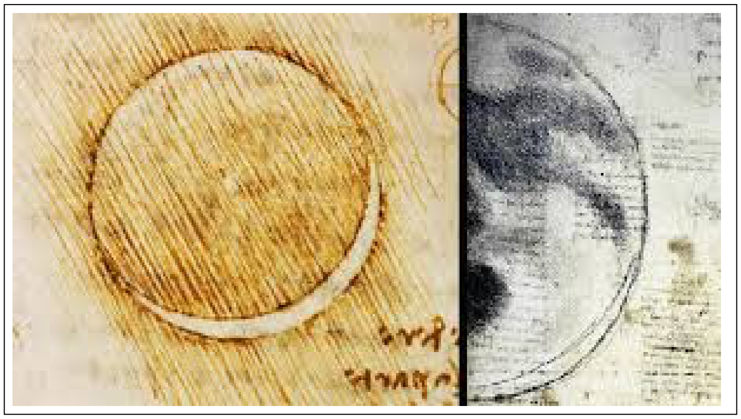


Figure 2.3: Two sketches of the Moon from da Vinci's notebooks drawn within the years 1506-1514: (Left) The crescent Moon with Earthshine (da Vinci, 1505-1508); (Right), a charcoal sketch of half a full Moon showing numerous maria including Crisium and Nubium (da Vinci, 1513-1514).

The Renaissance sparked a renewed interest in the arts, literature, and sciences which provided a catalyst for independent thinking, apart from church and state. Additionally, the invention of the printing press played a pivotal role by providing the means of sharing concepts, philosophies and images. The combination of these two influences expanded literacy as never before possible, which set the stage for scientific revolution by loosening the hegemony of the church (Nguyen, 2017). Europe's Age of Enlightenment in the 17^{th} century further provided impetus for the development of reason and individualism, rather than tradition, which in turn, increased the influence of science and the exploration of culture as a whole (Barentine, 2015).

2.1.2 Galileo Galilei

The predecessor of 20^{th} century space science, astronomy, is often called "the first science". Although now synonymous with his name, Galileo Galilei did not originally invent the telescope. The first recorded idea of a telescope was found in da Vinci's to-do list, noted in the *Codex Atlanticus*, "construct glasses to see the moon magnified" (da Vinci, 1513-1514). In 1608, Hans Lippershey, a German living in Holland, first unsuccessfully attempted to obtain a patent on his telescope. A year later, in 1609, Galileo improved Lippershey's design and began recording his scientific observations.

Galileo is regarded as the founder of modern astronomy, and his 1610 book *Sidereus Nuncius* is the first published book about the Moon based on telescopic observations. Figure 2.4(a) depicts his drawings of the lunar surface (Galilei, 1610).

(a) (b)

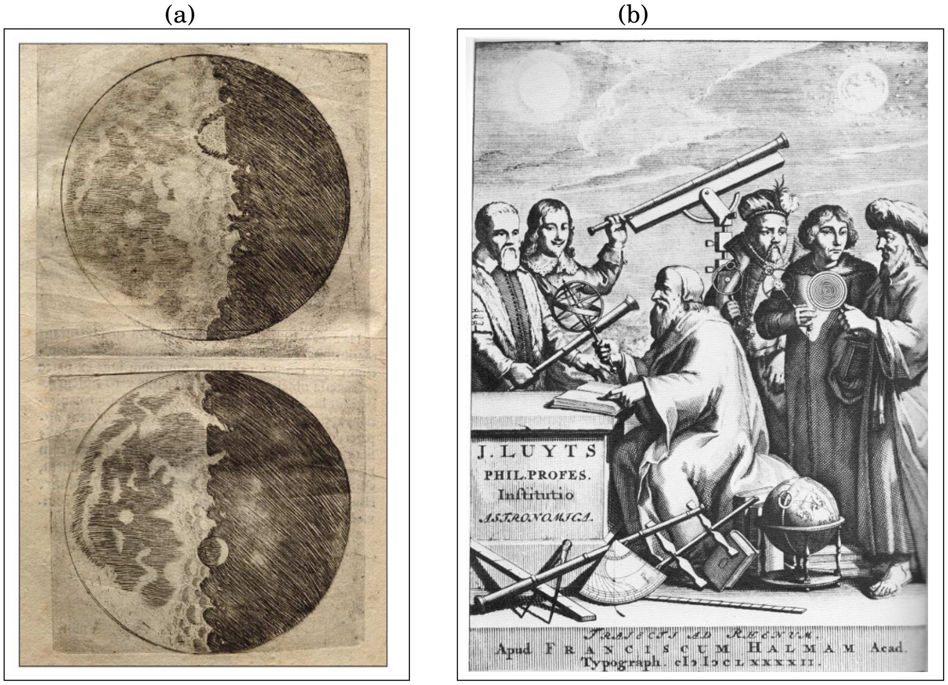


Figure 2.4: (a) Some of Galileo's Lunar sketches from the *Sidereus Nuncius* manuscript, fol 10v, watercolour, 1610 (Galilei, 1610); (b) Artist Unknown, *Early Astronomers* engraving, 1692. Left to right are Galileo, Hevelius, Aristotle, Brahe, Copernicus, and Ptolemy (Luyts, 1692).

Astronomers had to become artists by default to be able to illustrate what they saw through their lenses. Galileo was fortunate, his early training in art and mathematics served him well. His chiaroscuro technique of contrasting of light and shade, as well as his understanding of the principles of contrast and perspective and enabled him to depict accurately what he had seen, and to be able to speculate on its meaning. Galileo also possessed a spectacular visual memory, as he only painted his lunar images from memory a year later so that they could be reproduced as engravings for his book *Sidereus Nuncius* (The Starry Messenger) in 1610.

The telescope's impact on society was dramatic: it immediately caught the public's imagination and popularized astronomy. Artists were called upon to celebrate astronomy's lineage as illustrated in the engraving shown in Figure 2.4(b). Indeed, optics were the new magic, and produced wonder and awe from the detailed observations that had never been seen before. Astronomy became the new science (Pearce, 2017), empirical evidence became the new truth and astronomical art became fashionable.

Scientists and their work, too, came under the scrutiny of the artistic imagination. Newton's concept of a universe governed by rational laws proven by experimentation were essential for transforming natural philosophy into science and a cornerstone of Enlightenment Era thinking. Thus Professor Marek Dominiczak of Glasgow University describes Newton as holding a transitory position, as he spanned the disciplines of alchemy, theology and science, when science was just beginning to separate into its own discipline.

Artists illuminate and document the import of scientific advancements, as illustrated in Figure 2.5 *"Allegorical Monument to Sir Isaac Newton*, painted by Italians Giovanni Pittoni, Domenico Valeriani, and Giuseppe Valeriani, during the years 1727 - 1729. In this theatrical scene, gods and ancient scholars are animatedly conversing in front of the imaginary tomb of Isaac Newton. In the centre, midground, Newtonian optics are being demonstrated by the splitting of white light into different colors via a prism (Dominiczak, 2012).

Newton's studies of refraction, reflection and the colors of light enabled artists to become more sophisticated with their use of light and color. These particular painters of the *Allegorical Monument*, though, did not understand the refraction angles sufficiently to represent them accurately. This brings to bear the necessity of communication between artists and scientists, because this painting will be forever illustrating the wrong information although oil is a medium that could have been corrected at the time it was painted (Shuttleworth, 2011).

Artists were keen to take advantage of the contributions that the scientific revolution could offer in terms of content as well as from the improved composition of paints, papers and canvases. The invention of the paint tube itself allowed painters to leave the studio and go outdoors for the first time, it also allowed the artist's imagination to soar in terms of experimenting with place, technique, light, color, shadow. And those experiments engendered new genres (Washington Academy of Sciences, 2019).

Figure 2.5: Allegorical Monument to Sir Isaac Newton, 1729. Giovanni Battista Pittoni, Domenico Valeriani, and Giuseppe Valeriani. Oil on canvas. Copyright: Fitzwilliam Museum, Cambridge (Dominiczak, 2012).

The evolution of the humanities, which encompassed the arts and sciences, was predicated on a curiosity about the natural world, and a thirst for knowledge available through observation. During the Renaissance and the Age of Enlightenment, polymaths were able to expand the standard of scholarship by achieving mastery in intellectual, artistic and physical pursuits, that also embraced a concept of universality and humanity.

Both Leonardo and Galileo were immersed in the scope of humanities in their time;

classical art, literature and philosophy. Both were gifted teachers, and argued passionately with other philosophers about the merits of art and of science. Leonardo was well rounded, generous, theatrical, dramatic, fanatically collected books, loved music, was well spoken, and possessed a beautiful singing voice (Issacson, 2017). Galileo's last student and biographer Vincenzo Viviani attested that Galileo was a great talent who delighted in drawing to the extent of attaining membership of the Art Academy of Florence (*Accademia del Designo*). If Galileo would have been free to choose his profession at an early stage he absolutely would have chosen painting (Roche et al., 2018).

Another biographer, Mark Peterson, points out Galileo was also an excellent lutenist and an accomplished composer. Peterson further extrapolates that it was the mathematics of renaissance arts, not the renaissance sciences that became "modern" science. Peterson argues that painters, poets, musicians and architects brought about a scientific revolution that eluded the philosophers because science of the day were still steeped in a philosophical concept of a medieval cosmos and in the grips of the church. The recovery of classical science philosophy, the precursor of modern science, should actually be credited to the artists who continuously referred to Greek culture for inspiration into mathematics ranging from perspective in painting to tuning in music (Peterson, 2011).

With the advent of the modern age, science replaced superstition. The influence of astrology declined, alchemists became chemists and physicists. Philosophers, scientists, and artists fomented the Industrial Revolution as engineers provided the machines for mass production (Shuttleworth, 2011). The rapid accumulation of knowledge and the subsequent need for increased specialization necessitated the separation of science from the humanities into a discipline of its own, and in doing so ended the age of the great genius polymaths.

2.2 A Polymathic Legacy

The polymaths of yore were the product of a particular age, when learning was a mark of distinction because only a few could afford the luxury. However, the enthusiasm for their subjects, the heated debates, that they could publish philosophic and scientific concepts and maintain libraries for the first time in history, all served as keystone events that accelerated the speed of the scientific revolution. Nonetheless, polymaths of the past continue to cast a long shadow.

Then as now polymaths have had to pay for their limitless curiosity and divided interests. They are often viewed through a lens of skepticism, their contribution less valued in commerce or academia than that of their specialized colleagues (Carr, 2009). That being said, the true value of a polymath's wide array of interdisciplinary knowledge is their ability to interconnect and integrate one subject into another. Although the era that spawned the Renaissance person has passed, the idea of the polymath as one who is capable of developing advanced ability in divergent multiple disciplines, has not (Friedman, 2018).

Today the definition of a polymath varies in scope and degree within the context of the era in which the polymath lived or lives. The criticism of a modern polymath would be that they are "all style and no substance". That the split in attention would necessarily create an individual who is not a heavyweight in any field, therefore the validity of their knowledge is suspect. One who is lacking the authority and weight, and a difficult person to accommodate in the academic sector, the governmental sector and the business sector. The sheer numbers of professionals now as compared to the past, the vast amount of knowledge arenas that have been defined by experts creates monomaths, and overwhelms the polymaths (Carr, 2009).

2.3 The Creative Imperative

"What is common to art and science? Creation. Or rather, the drive that impels creativity. The thrill of the word and sound, of the colour, lines and shapes of art. The temerity of the scientific hypothesis which extends beyond reality. What is the aim of a creative act in art or science? To surpass reality."

- Federico Mayor (Strosberg, 2015).

Being overwhelmed, underpaid and insecure are detrimental conditions for the nurturing of polymathic skills. Although often considered by colleagues as somewhat treasonous, polymaths are intrinsically compelled by curiosity to investigate any field that attracts their attention, even knowing that one is stepping into an arena in which others are more expert, that it is likely an economically unsound move, and that it carries the risk of being unfavorably compared with others past or present. With the onslaught of technology, the curiosity and creativity of the polymathic individual did not go out of fashion as much as it morphed into a polymathy of degree and scope, as the needs of a technological society dictated.

Following on from artistic and scientific polymath abilities exemplified by the dual pursuits of Leonardo da Vinci and Galileo Galilei, the next four examples illustrate the legacy of leading scientists who are iconic for the degree of their creative imperative in the arts: Johannes Kepler for writing science fiction, Max Planck for playing piano, Albert Einstein for playing violin and Richard Feynman for painting and drawing.

2.3.1 Johannes Kepler

"As soon as somebody demonstrates the art of flying, settlers from our species of man will not be lacking (on the Moon and Jupiter)"
- Johannes Kepler (Whitney, 2012)

As a child, German astronomer and mathematician Johannes Kepler (1571-1630) witnessed the Great Comet of 1577 (see Figure 2.6), which attracted the attention of astronomers across Europe. Kepler's major contributions to astronomy are his Laws of Planetary Motion, and a true description of the solar system. His polymathic inspirations included music, such as the "Music of the Spheres" concept that music of the universe was key to understanding the cosmos, as stated in his 1619 *Harmony of the World* (Peterson, 2011).

Kepler also ventured into fiction, with *Somnium* (The Dream), the first scientific storyline of the Moon as a destination. *Somnium*, written in 1608 but only published posthumously in 1634, revolves around a student of astronomer Tycho Brache being metaphysically transported to the Moon, and contains descriptions how the Earth might look from the Moon (Kepler, 1634). Biochemist/writer Isaac Asimov and cosmologist/writer Carl Sagan consider Kepler's book the first venture into the genre of science fiction novel authored by a scientist (Rosen, 1967).

Figure 2.6: *A depiction of the Great Comet of 1577 over Prague* - Engraving made by Jiri Daschitzky. In addition to the comet, five zodiacal symbols appear in the sky: (L-R) Aries, Pisces, Aquarius, Capricorn, and Sagittarius. Below the comet's tail are the crescent Moon and Saturn, depicted as a star with the astronomical symbol ♄. At the bottom center, a man draws the comet by the light of a lantern (Daschitzky, 1577).

2.3.2 Max Planck

"The pioneer scientist must have a vivid intuitive imagination, for new ideas are not generated by deduction, but by artistically creative imagination"
- Max Planck (Gaither and Cavazos-Gaither, 2008)

Max Karl Ernst Ludwig Planck's (1858-1947) origination of the quantum theory marked a turning point in the history of physics, for which he was awarded a Nobel prize in 1918. However, he was also a gifted pianist who delighted in playing the works of Schubert and Brahms. Figure 2.7 shows a portrait of Planck as a university student, aged 20. He chose physics as a career instead of music only because he felt he could make more of an individual mark in the field of physics.

Music was always near and dear in Planck's life, he composed classical music, held con-

Figure 2.7: Max Planck in 1878, age 20, photographer unknown (Planck, 1878).

certs at his home, and had a harmonium especially built. He also played the cello and piano expertly, had perfect pitch, a beautiful singing voice, and sang in the university choir (Stuewer, 2019).

Physicist and author Freeman Dyson describes the fortuitous occasion when Planck and Einstein met, and reports that Planck was one of the first scientists to recognize the importance of Albert Einstein's work. When Einstein sent five papers to a physics journal in 1905, they landed up on Planck's desk. Planck recognized them for their import and published them immediately, waiving the necessity of the input from peers. Almost a decade later Planck assisted Einstein to move to Berlin and take up a professorial position in 1914. Later they would enjoy playing music together (Freeman, 2015).

2.3.3 Albert Einstein

"All religions, arts and sciences are branches of the same tree. All these aspirations are directed toward ennobling man's life, lifting it from the sphere of mere physical existence and leading the individual towards freedom. The greatest scientists are artists as well"
- Albert Einstein (Waldrop, 2017)

Albert Einstein (1879-1955) began his violin instruction at the age of six and his mother, Pauline, an accomplished pianist herself, also taught him piano. Music became central to Einstein's mental and emotional processes; he would play classical music on violin and piano as a brainstorming technique.

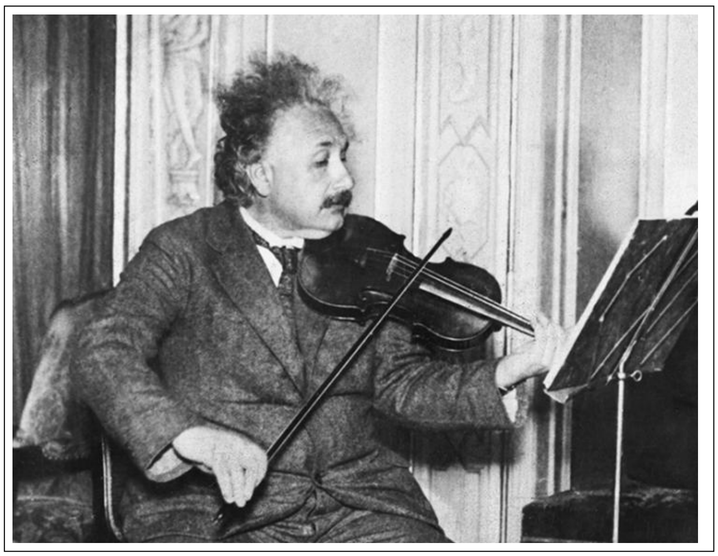


Figure 2.8: Albert Einstein and "Lina", his violin (Waldrop, 2017).

Einstein's biographers often mention that Einstein saw Mozart as a kind of musical physicist; *"someone who seemed to find his distinctive sound in the most cosmic essence of harmony."* Rarely would Einstein leave his home without carrying his music and often his violin. Einstein hosted weekly chamber music sessions at home, and he played impromptu violin serenades in the streets, surprising passers-by at Halloween and at Christmas (Waldrop, 2017). Like Planck, music was Einstein's plan B in terms of careers.

"The theory of relativity occurred to me by intuition, and music is the driving force behind this intuition. My parents had me study the violin from the time I was six. My new discovery is the result of musical perception"
- Albert Einstein (Root-Bernstein and Root-Bernstein, 2010)

2.3.4 Richard Feynman

"I wanted to convey an emotion I have about the beauty of the world... this feeling about the glories of the universe"
- Richard Feynman (Feynman and Leighton, 1997)

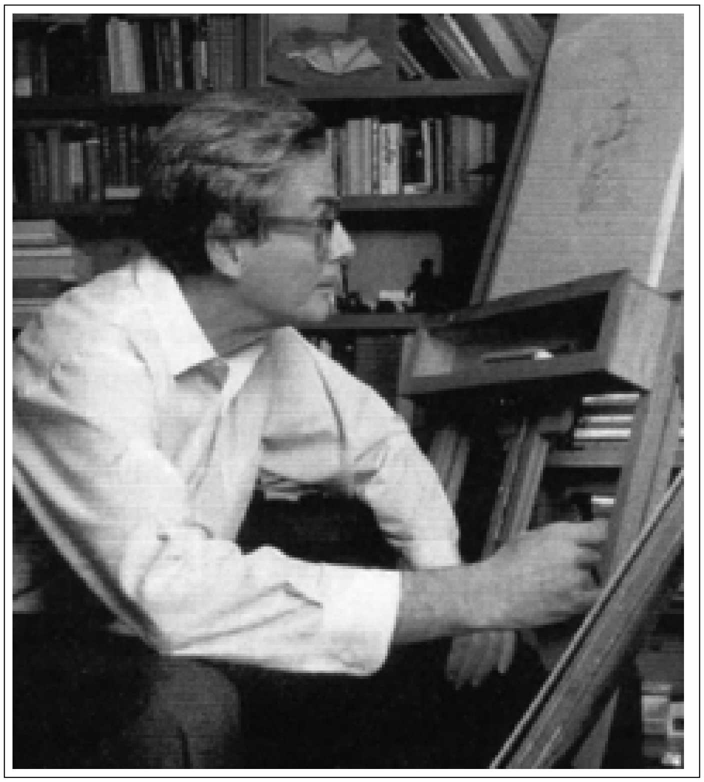


Figure 2.9: Richard Feynman in his studio (Sourced from personal files).

Theoretical physicist Richard P. Feynman (1918-1988) was awarded the Nobel prize in physics in 1966. He became a Professor at Cornell University and Caltech, and was particularly known for quantum physics, quantum electrodynamics, particle physics, quantum computing and nanotechnology. Feynman was also well known among his colleagues for his sense of humor, his love of life, and his passion for sketching and painting. He began his art lessons in 1962 at age forty-four and enjoyed some notoriety with his exhibitions. After thirty years of drawing he filled over 100 sketchbooks which does not include the number of his finished drawings and paintings. If he would have had more time to devote to his art, he could have easily developed into a professional artist.

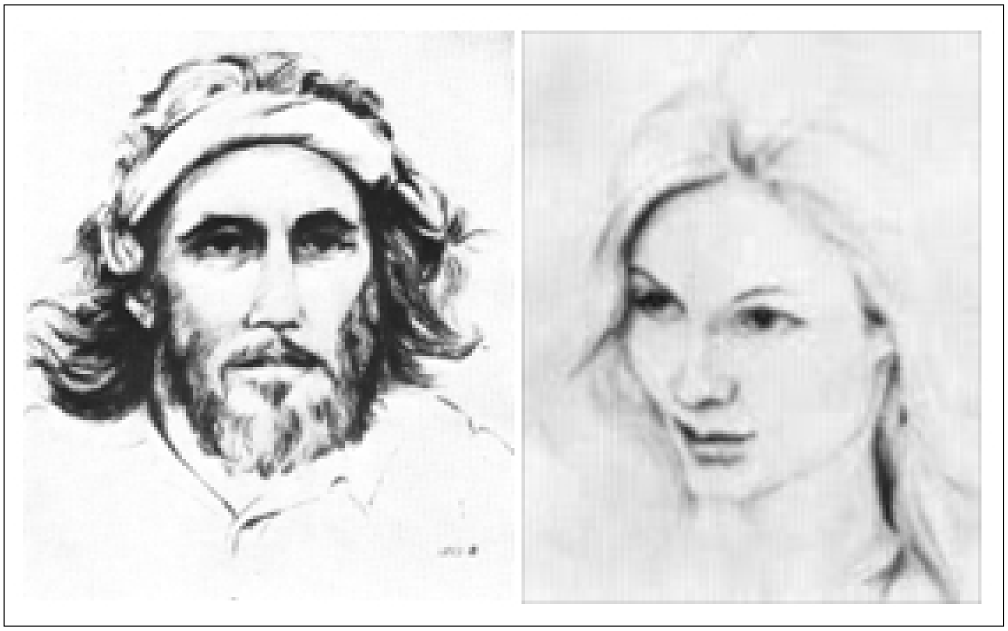


Figure 2.10: The Art of Richard Feynman: (Left) Portrait of a Man, date unknown; (Right) Portrait of a Woman, date unknown (Kaushik, 2009).

"I wanted to convey an emotion I have about the beauty of the world. It's an appreciation of the mathematical beauty of nature, of how she works inside, a realization that the phenomena we see result from the complexity of the inner workings of atoms; a feeling of how dramatic and wonderful it is. It's a feeling of awe, of scientific awe, which I felt could be communicate through a drawing to someone who had also had this emotion"
- Richard Feynman (Feynman and Leighton, 1997)

What is perhaps lesser known is Feynman's synaesthesia, a perceptual phenomenon in which stimulation of one sensory or cognitive pathway leads to automatic, involuntary experiences in a second sensory or cognitive pathway.

"When I see equations, I see the letters in colours - I see vague pictures of Bessel functions from Jahnke and Emde's book, with light-tan j's, slightly violet-bluish n's, and dark brown x's flying around. And I wonder what the hell it must look like to the students"
- Richard Feynman (Feynman, 1988)

Synaesthesia is a capacity which was described by Newton, written about by Kant and Goethe, and another sensory perception which scientists and artists share, as most people with synaesthesia are drawn to the fields of art or science. Feynman is in the company of

Vladimir Nabokov, Vincent van Gogh, Nikola Tesla and Itzhak Perlman, among others. How synaesthesia affected his science, or his art work and that of other scientists/artists, would be a fascinating ongoing study. Of late, both polymathy and synaesthesia have captured the interest of researchers who study the creative process.

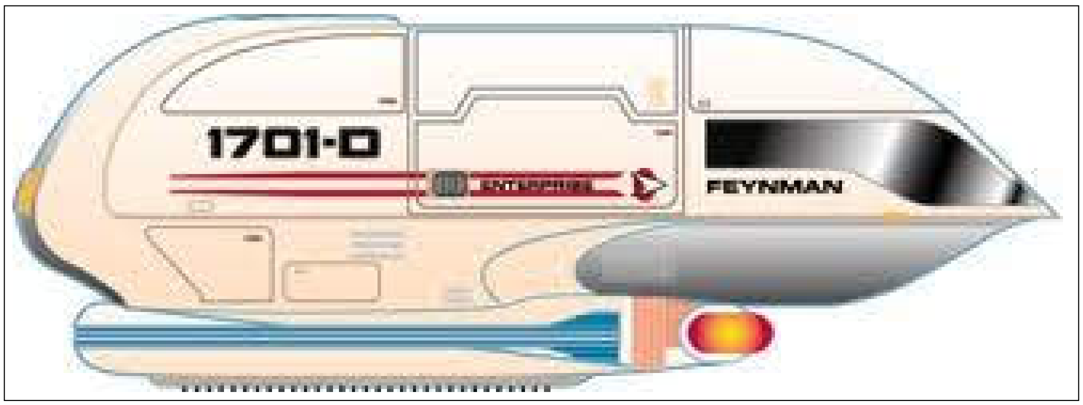


Figure 2.11: Feynman was honored by the producers of *Star Trek: The Next Generation* by having a shuttlecraft named after him. The shuttle is featured in the 1997 episode titled *Chain of Command (Part I)* (Drexler, 1997).

Space art and space science arose from a history fraught with antagonism between their forerunner disciplines of the arts/humanities and the natural sciences. This cultural animosity was entrenched for centuries, irrespective of luminaries such as da Vinci, Galileo, Kepler, Planck, Einstein, and Feynman having communicated the value of their own polymathic Art/Science experiences in their working lives. However, the arrival of the space age and its constant need to push the boundaries of creativity opened up new inquiries into the value of art to science and the need for professionals who migrate between the two.

2.4 Common Ground

The inclination to compare artistic and scientific similarities was sporadic at best throughout the 19^{th} century. The acceptance of the traditional categorization that art is solely in the realm of imagination, emotion and creativity, while science is solely a matter of reason, accuracy and methodical process forestalled any serious examinations of the creative processes they both used. Therefore, it was assumed that a comparison of the two fields would have no intrinsic value because there was no common ground.

That reasoning became moot in 1957 when the phenomenon of Sputnik, the first human-made satellite orbiting the world, demanded a game changing response. American technology needed to reciprocate, thus innovation and creativity became essential commodities for space science problem solving. The necessity to grow space capability exponentially in and of itself elasticized the boundaries of applied sciences, arts and philosophy. With President Kennedy's mandate for a crewed moon landing only a couple of years away, the condition of having the artistic/intellectual and scientific information systems at odds with one another could put the mission in jeopardy.

Frank Malina, who stood squarely in both camps of the arts and sciences, clarified the relationship and redefined the boundaries of the disciplines, and Stephen Wilson interrogated the dynamics of the of the Art/Sci relationship to comprehend the legitimacy of their methods of inquiry.

2.4.1 Frank Joseph Malina

Pioneering astronautical engineer, co-founder of National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), painter, and kinetic artist Frank Malina (1912-1981) reflects on the differences between the concepts of Science and Art in his 1968 article *Directions in Art Theory and Aesthetics*.

In it, he predicts that the estrangement of the arts and sciences will likely continue because science hasn't made its objectives clear in terms artists can comprehend, and those who speak for the arts haven't put forth a hypotheses that garners the respect of science, or of other artists in general. In an effort to inject clarity into the misunderstandings, Malina went back to the basics, and offered the following explicit definition of the realms of each discipline and their value to society (Malina, 1968):

Art

The chief purposes of the visual arts are, by means of artifacts, to stimulate and satisfy human emotions, to help the human mind to comprehend the knowledge and conceptions of the universe and of the world to widen and deepen emotional perception of selected portions of the human environment. The theoretical basis of art is the concern for aesthetics - Frank Malina

Science

The word science covers the wide range of human activities stretching from the accumulation of knowledge about the myriad relationship to the physical universe and the world of humans, to the application of that knowledge for the satisfaction of human needs, dreams and desires - Frank Malina

Malina drew on his own polymathic endeavors to conclude that the arts and sciences were fundamentally related in that the human imagination and passion drove both scientific, engineering and artistic discovery (Malina, 2013).

Another of Frank Malina's legacies is his founding of the art/technology/science journal *Leonardo* in 1967. Originally developed as a communication channel for artists, in the ensuing years it has expanded to include papers from scientists, engineers and scholars in the fields of the arts and science. Frank's son, physicist, astronomer, and author Roger Malina has expanded *Leonardo's* content to include a music journal in 1991.

Leonardo has become a globally renowned peer review journal that has published over 4,500 papers. *Leonardo*'s growing influence as an International Society for Arts, Science, and Technology, is a platform that is demonstrably setting the narrative at international conferences to promote and publicize the intersection of the arts, technology, the sciences, and their value to society.

Roger Malina recognizes the polymathic ability of his father and those like him, and the role they played during the development of the space age. Roger refers to polymaths as today's "hybrids" (those who have dual careers in the arts and sciences). Although they were few and far between then, today is a different story. They are spread among the fields of science and engineering in universities and industry, and have, indeed, become a phenomenon. Those

(a)

(b)

Figure 2.12: (a) Frank Malina in studio creating *Cosmos* (McCray, 2015); (b) *Cosmos* (1965) stands 9 ft 6 inches high and 8 ft wide. Drawing from an early age, Malina became a painter, then developed Lumidynes, a kinetic light painting process, using light, rhythm and motion as a pictorial composition to combine dynamic rhythm with elements of stasis (Gadney, 2015).

artists and scientists who, by virtue of the overarching demand of creativity to be in service to innovation, have emerged in a pivotal new role as "Translators" for different knowledge sets. Malina describes a whole new class of professionals: those who are mobile and navigate in transdisciplinary practices (Malina, 2013).

"This emerging hybrid community is carrying within it the ideals of a socially robust science that not only foregrounds ethics and values as core values in science and engineering but also celebrates the joy and pleasure of the well-being of human beings in all their irreducible complexity"

- Roger Malina (Malina, 2013).

2.4.2 Stephen Wilson

Computer artist, researcher, scholar and author Stephen Wilson (1944-2011) was head of the Conceptual Information Arts department at San Francisco State University and focused on the intersections of art, science, technology and culture. In 2002 he authored *Information Arts: Intersections of Art, Science, and Technology*, a compendium detailing their dynamic interrelationship as both methods of inquiry operate at the frontier of knowledge (Wilson, 2002). The differences between Art and Science are discussed in Table 2.1:

Table 2.1: The differences between Art and Science.

Art	Science
Seeks aesthetic response	Seeks knowledge and understanding
Emotion and intuition	Reason
Idiosyncratic	Normative
Visual or sonic communication	Narrative text communication
Evocative	Explanatory
Values break with tradition	Values systematic building on tradition and adherence to standards

The similarities between Art and Science are (Wilson, 2002):

- Both value the careful observation of their environments to gather information through the senses.
- Both value creativity
- Both propose to introduce change, innovation or improvement over what exists
- Both see abstract models to understand the world
- Both aspire to create works that have universal relevance

2.5 The Art/Sci Dichotomy Demystified

Contrary to the historic dichotomy, and furthering the logic of Malina and Wilson's thinking, current research indicates that the characteristics and processes of artists and scientists are not only similar, but often overlap to the point of the practitioners being polymathic. Overlapping polymathic ability in both the arts and sciences are instrumental in nurturing two essential qualities necessary for meaningful artistic expression and successful space exploration: creativity and innovation.

Closer attention is now being paid to the process of creativity that leads to innovation because there are two key elements that underpin the activities of the business community, the science community, governmental and Non Governmental Organization (NGO) entities, the art community and society at large. That the process of innovation has been historically linked to the process of creativity itself is the reason that academics and scientists are giving artists a second look. Specific studies involving comparison of the polymathic talents between visual artists and space scientists are atypical, since the disciplines have been considered so diverse as to not warrant a comparison - a faulty judgment according to academicians Robert and Michèle Root-Bernstein, Michael Espindola Araki and Waqās Ahmed.

2.5.1 Robert and Michèle Root-Bernstein

The studies of educationalists Robert and Michèle Root-Bernstein of Michigan State University involving creativity in the realm of arts-sciences interactions lead them to conclude that although the products of the disciplines are indeed different in both aspect and purpose, the processes used by artists and scientists to forge innovations remain extremely similar.

Compiling extensive research from numerous studies, the Root-Bernsteins' assessment is that an unexpectedly high proportion of scientists are amateur to professional artists, and that arts and science are part of one common creative culture composed of largely polymathic people (Root-Bernstein, 2008). They present five types of evidence that correlate artistic and scientific attributes to support their conclusions that arts foster science and science fosters art.

Successful artists and scientists tend to be polymaths with unusually broad interests, and training that transcends disciplinary boundaries (Root-Bernstein and Root-Bernstein, 2010):

- Artists and scientists have similar psychological profiles as determined by widely used psychological tests. (as differentiated from those in business, for example).
- Arts proclivities predict scientific success, just as intellectually challenging avocations predict success in all fields.
- Scientists and artists often describe their creative work habits in the same ways, and use common interdisciplinary mental tool kits.
- Scientists often state that their art avocation fruitfully informs their vocation, artists often draw explicit sustenance from their scientific interests.
- The arts have often stimulated scientific discoveries and scientists has also influence the nature of artistic creativity.

The visual arts by tradition have been bundled within the auspices of the Humanities, which include the philosophy, liberal arts, literature, classical studies and language. We note here that the historical dissention between the two disciplines was more specifically between the philosophical element of the humanities versus the natural sciences, and certainly not between the artists or scientists themselves. Artists were intrigued by astronomy and they sought to synthesize everything new that could enrich their art.

As more studies concentrate on polymathic individuals who practice both art and science, one can extrapolate that they do not necessarily fall into one category or the other. The borders would be blurry. It is not a strict either/or categorization, nor in this day and age, does it need to be. The polymathic interdisciplinary ability is at the core of innovation because the facility they possess to amalgamate elements previously not considered as related can be brought to bear on a design problem or an invention.

The Root-Bernstein's research conclusions on polymathy's relation to creativity & success are (Root-Bernstein and Root-Bernstein, 2004):

- Polymathy of any sort is highly correlated with vocational success.
- The more artistic avocations a scientist engaged in as an adult, the greater their possibility of achieving eminence in science.
- The cognitive styles of the scientists were correlated to their avocations.
- That Nobel prize winners practice creative writing and visual arts at rates many times higher than those of average scientists
- Their conclusion: that creative scientists have the psychological profile of artists, and more often than not, are artists.

The Root-Bernstein's years of research have legitimized polymathic ability in academia and adjacent circles. The result has promoted a growing interest in researching the advantages of a polymathic approach in fostering innovation and creativity across a wide spectrum of fields heretofore considered unrelated.

2.5.2 Michael Espindola Araki

Author and academic Michael Araki recognizes the need to analyze the nature of each component of polymathy to determine how to best systematize the phenomenon to give rise to generalizable findings. In doing so, Araki finds that the core dimensions of the polymathic approach can be reduced to the common denominators of breadth, depth and integration. Breath refers to the comprehensiveness and variety of knowledge and distance between the disciplines (i.e. arts and sciences). Depth gauges the quality of the interest in and the degree of the knowledge procured: the dilatancy as compared to the profoundness of the knowledge.

Integration encompasses broad learning, the ability to synthesize information from disparate knowledge bases and striving to create new knowledge. In this era of fragmented knowledge (inherited from the age of industrialization) the end goal is to create synergies between disciplines where none existed at the intersection of multiple domains and between different bodies of knowledge. Thus, the ability to recombine and synthesize knowledge is the core value of a polymath (Araki, 2018).

2.5.3 Waqās Ahmed

In *The Polymath, Unlocking the Power of the Human Versatility*, Waqās Ahmed chronicles polymathy through ancient civilizations of the East, West and Africa, and projects it beyond the 21^{st} century. Ahmed's work reveals that polymaths were some of the most influential figures in world history, and instrumental in shaping the modern world. He concludes that creativity at the art - science intersection has been evident throughout history, and as such, it demonstrates of the importance of and potential of interdisciplinarity. The visual, literary and performing arts have always attracted polymaths as their practice involves multiple avenues for creative expression. Science and technology have also used art as a vehicle to excel and vice versa (Ahmed, 2018).

Artists and scientist alike are drawing on the same imaginative capacities of the mind, and endure the same struggle to apprehend their multifaceted ideas. To take advantage of this polymathic propensity, Ahmed envisions a cognitive and cultural revolution to educate a new generation of polymathic minds to take stewardship of the future, thereby engendering a highly motivated, well equipped society to address the complexity of the 21 century challenges (Ahmed, 2018).

2.6 The Rise & Decline & Rise of the Polymath

Over the past centuries the nature of intellectual endeavor has changed profoundly. The polymaths of old became redundant in the face of technology. The question for this study is one which Edward Carr also considered: did polymathy outlive its usefulness in the 18^{th} century, only to resurface hundreds of years later to be the saving grace of an innovation-dependent world looking to save the planet by exploring space?

Polymathy in the arts and sciences have been in the forefront of instituting collaborations, and has filtered into public awareness through media via educational talks, academic articles, papers and interviews for over a decade. The phenomena is presented by educationalists as an exciting way to access one's natural propensities to increase creativity in service of technological innovation, and have fun along the way.

One detriment to moving polymathic ability out of the status of an avocation and into the arena of a vocation is the cost of the education, and the time allocated for learning more skill sets. Also, at issue to overcoming both stereotypes of polymaths as knowing too little about too much, and specialists only possessing tunnel vision in their area of expertise. The relationship between the two need not be adversarial, as there will always be endeavours that will require specialists and others that will require generalists. There will be a lot more overlap of activity between the two, and they will have to become adjusted to working in each other's worlds.

Being a polymath is more than just having two or more interests in vocational and avocational activities. Rather, it is an automatic transference between those two mindsets. Araki compares the state of being polymathic to the facility of multi-tasking and raises it to the level of both an art form and a morality play. He also perceives polymathy at its best, reflecting back to the original moral and social responsibility that the privilege of knowledge evoked in the polymaths of yesteryear's Renaissance.

"A polymathic person places cardinal value upon and is driven toward two principal goals: the development of a conscience with as much richness of knowledge and experience as possible and the exercise of one's own agency to enhance and transform the world by their contributions."

- Michael Araki (Araki, 2018)

The rise of the space age itself has provided an opportunity for the rise of the polymath with the assumption that a polymathic skill set will better equip space scientists and space artists to find solutions to problems when facing the new frontier ahead of them.

CHAPTER 3

The Endless Horizons of Space Art

"Space Art... a noble genre of art reminds us of the delight and inspiration we have been given by astronomical artists all over the world and throughout out time. It is a marvelous celebration of their soaring imaginations, technical skills and artistic talents. And for me, will hereafter be a means to recall the special bond that joins them to us scientists. For, like scientists, astronomical artist are romantics, dreamers and explorers, ever yearning, ever seeking, ever hopeful."

- Carolyn Porco (Miller, 2014)

The universe, its vast expanse, its planets and what might be on them, is the basis of space art and the interrelationship between space art and space science. As demonstrated by the earliest evidence on cave walls that depict celestial events, to art that has been placed on the Moon, Mars or in orbit up until current day, artists strive to formulate that which they can see in space via technology, and that which they can still only imagine.

The term "Space Art" describes a relatively new genre, obtaining its name and classification from its subject matter. The genre gained its provenance from developments in compelling fiction, science fiction, and as a result of the development of space science. Space art can be divided into Astronomical Art (which depicts the cosmos) and Astronautical Art (which is chiefly concerned with depicting spacecraft, astronauts, habitats and activities). There will be overlap, as astronautical art is likely to be framed in an astronomical setting.

Space Art came into its own when satellite cameras captured photographic and film images progressively more accurately, offering a new platform for the artists' imagination. Which is to point out that it is where cameras cannot go, the angles they cannot capture that benefit from the images by traditional artists, graphic artists and animators. In the mid 19^{th} century French painter and lithographer Honoré Daumier was quoted as saying *"Photography imitates everything and expresses nothing."* In other words, although the camera may record a scene accurately, it actually comprehends nothing; therefore an artistic eye must be employed to contextualize the images and present data graphically in such a way that they can be fully comprehended and appreciated by both the scientific and non-scientific viewer. These are scientific functions in which artists excel. From an artist's point of view, though, that is only one portion of Space Art's domain. Astronomical artists also deduce plausible scenarios from the available facts when they interpret scientific data for use graphically in the creation of a painting (Dixon, 2017).

To fulfil the imaging requirements demanded by space agencies, astronomers, scientists, engineers, educators and academicians, artists began incorporating multi-disciplinary skill sets into their portfolios, covering photography, visual arts, illustration, computer-aided design and multimedia, to demonstrate the fulsomeness of the space experience. One result of those requirements involved artists who cross the traditional arenas of illustration and fine arts. That illustration is a trade which usually requires exact rendering or computer-aided design does not define or limit illustrators, animators or graphic artists from including dimensions of the fine arts such as color, line, shape, texture and light into their work. Many visual artists apply their talents as illustrators and the reverse.

The influential arena of media, too, at once creates and fulfils an ever-increasing demand to provide captivating imagery of what space is or could be like. To express complicated astronomical concepts and renderings of space phenomena which have never been or may never be photographed, have provided a platform for the cross over between the disciplines of illustration and fine art. This chapter presents a historical timeline of five polymathic individuals whose vision enriched the astronomical arts and also furthered the science of astronomy. One could say they "engineered" space art by combining their astronomical observations with their painterly imaginations. The remainder of this chapter covers the theoretical aspect of space art, and illustrates its purpose, its categories, and its functions.

3.1 The Polymathic History

In the era before Sputnik orbited around the Earth and precipitated the Space Age, and the sea change in space science and space art that followed, five polymathic artists/scientists stand out. They have become iconic, some even obtaining a cult status for historians and art collectors. They are James Nasmyth, Scriven Bolton, Lucian Rudaux, Chesley Bonestell, and Ralph Smith.

3.1.1 James Hall Nasmyth

Engineer, Artist, Astronomer

James Nasmyth (1808-1890) was a Scottish engineer, artist, philosopher, and inventor. Although born into an artistic family and having attended Edinburgh School of the Arts, Nasmyth first gained notoriety for his invention of the steam hammer. After inventing various foundry machines, at age 48, Nasmyth devoted himself to astronomy and photography, and built a 20-inch reflecting telescope. Nasmyth's remarkable illustrations of the Moon were created by combining sculpture and photography. Nasmyth set his scenes by sculpting plaster models of lunar features, then photographed them using pinhole camera photography (Dixon, 2017).

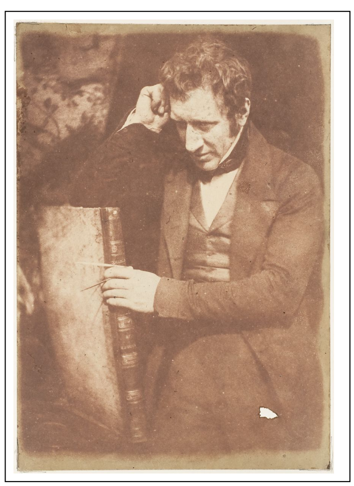


Figure 3.1: James Hall Nasmyth, circa 1844 (Hill and Adamson, 1847).

As seen in Fig 3.2, Nasmyth rendered accurate views using both his telescope and his deductive reasoning; such as Earth eclipsing the sun as seen from the Moon's surface, the refracted ring of red light that renders the Moon dark red when it passes through Earth's shadow, the "diamond ring effect" around the Earth that occurs during a total solar eclipse, and the correct size ratio of the Earth.

Figure 3.2: *Lunar Eclipse* by James Nasmyth, 1874 (Nasmyth and Carpenter, 1885).

After developing the photograph, Nasmyth further retouched it with ink to create shadows and atmospheric colors (Dixon, 2017). It is a technique that is still being used by space artists. The illustrations in his book (written with James Carpenter), *The Moon: a Planet, A World, A Satellite* was published in 1874 to widespread acclaim, based on the extraordinarily detailed images and the reputations of its authors. This made his artwork the first space landscapes to appear in a nonfiction book (Miller, 2014).

3.1.2 Thomas Simeon Scriven Bolton

Artist, Illustrator, Astronomer

An astronomer, a skilled artist and a commercial illustrator specializing in astronomical subjects, Scriven Bolton (1888-1929) produced a substantial body of work which was reproduced in a wide range of publications including newspapers, magazines and books in Europe and North America. Scriven was proficient in depicting space through the telescope, with his unaided eye or from his imagination.

Bolton used a 26-inch telescope and established a private observatory, equipped with an 18-inch reflector. For a period of seven years he carried out studies of variable stars, which were published by the Royal Astronomical Society. In many of his depictions of other worlds, Bolton's technique was similar to Nasmyth's. Bolton's work was known to Lucien Rudaux and Bolton introduced Bonestell to the genre when they both worked together in London during the 1920's. Bolton (shown in Fig. 3.3) also sculpted plaster models of the object's surface, photographed the diorama, then painted other details onto the final photographic print (Davenhall, 2012).

Figure 3.3: Scriven Bolton projects a solar image onto a small, portable transit instrument in this 1907 photograph (Davenhall, 2012).

Bolton became a Fellow of the Royal Society of Arts. He wrote and illustrated 13 articles for the magazine *Popular Science*. Bolton's astronomical specialization allowed his work to also be considered apart from the written word, and as such was considered as an artwork on its own. Those artworks were published in *The Illustrated London News*, a lavishly illustrated newspaper popular in the late 19^{th} century (Miller, 2014).

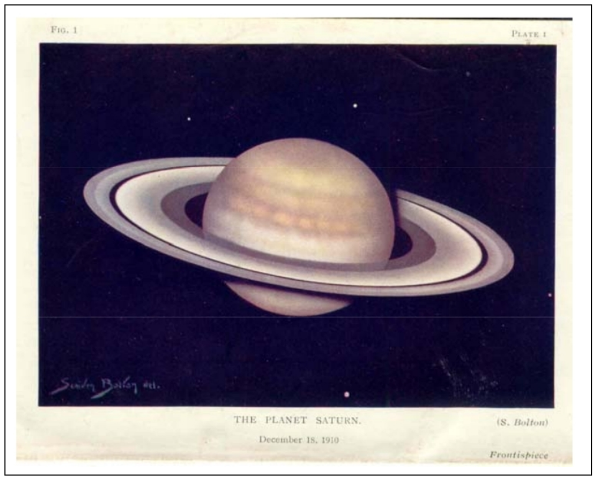


Figure 3.4: *The Planet Saturn* by Scriven Bolton, 1910, which served as the frontispiece to G.F. Chamber's 1912 *Astronomy* (Miller, 2014).

3.1.3 Lucian Rudaux

Artist, Illustrator, Astronomer, Writer

Frenchman Lucian Rudaux (1874-1947) is considered the grandfather of the astronomical art genre because of his scrupulous scientific observation and his meticulous fine art technique. Using a 4-inch reflector, he observed the limb of the Moon and was the first to paint the Moon's mountainous surface as rounded, a theory later proven accurate by satellite photography.

Figure 3.5: Lucian Rudaux in his private observatory at Donville-les-Bains, Normandy (Normandy Then and Now, 2018).

Rudaux took on not only the representation of the Moon, but also the planets and the Milky Way. He visualized Venus as an eroded and rocky place, and Mars as a dust-storm-swept rock-strewn plain. He produced portraits of Saturn and Jupiter as seen from their respective satellites. Rudaux's paintings often resemble NASA photographs, yet they were produced far before anyone photographed the planets or set foot on the Moon (Miller, 2014).

In 1928 Rudaux produced *Sur Les Autres Mondes (On Other Worlds)*, which contained 400 illustrations of the solar system. It was his eye for astronomical detail and dedication to painting that garnered him the first entry into the International Association of Astronomical Artists (IAAA)'s Hall of Fame. His name also graces their award for lifetime contribution to the astronomical arts (IAAA, 2000).

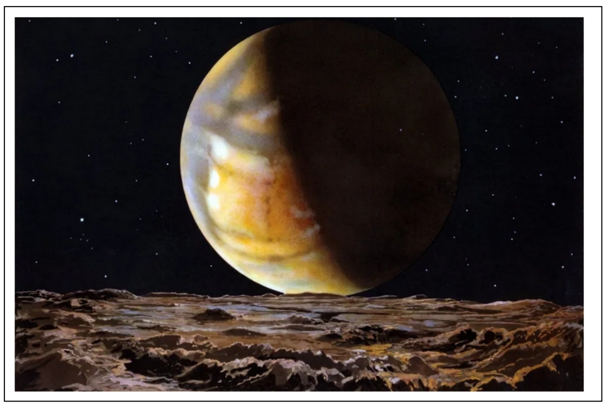


Figure 3.6: Mars as seen from the surface of its satellite Deimos. Rudaux's creations were astonishingly accurate, even by today's standards (Miller, 2012).

3.1.4 Chesley Knight Bonestell

Architect, Astronomer, Artist

Inspired by Scriven Bolton, Chesley Bonestell (1888-1987) earned the title "Father of Modern Astronomical Art" because his polymathic talent was so diverse and his art work so persuasive that he was able to shape the mindset of his professional colleagues and the general public alike as to what the surfaces of planets or future spacecraft could look like. Because Bonestell was able to adapt his work to fit any form of media, he contributed to the explosion in space art books, magazines, television, poster art and film.

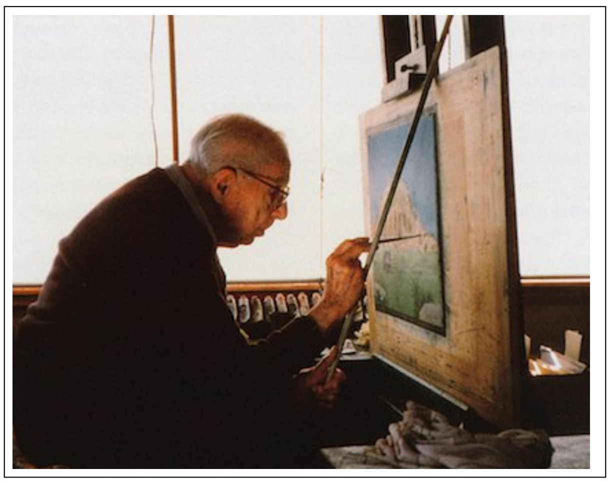


Figure 3.7: Chesley Bonestell at his easel (DMS Production Services, 2018).

Bonestell was certainly the right artist with the right skill set at the right time. He had acquired a unique set of skills developed from his Hollywood years as a special effects mat painter to create a believability, a certain credibility that was a level above merely an artist's impression. Bonestell used his knowledge of camera angles to imbue his paintings with the reality of photography, and his architectural background to depict perspective, mass and visual angles (IAAA, 2000).

Bonestell's unique abilities and prolific output raised the bar for astronomical artists. Bonestell was still painting when he was over eighty years old, and during his life he had the opportunity to collaborate with writer and amateur rocketeer Willy Ley, nicknamed the Prophet of the Space Age, on *The Conquest of Space* and *Beyond the Solar System*. Bonestell also teamed up with Wernher von Braun in *Conquest of the Moon* and Arthur C. Clarke in *Beyond Jupiter* (Miller, 2011).

Figure 3.8: *Exploring the Moon* by Chesley Bonestell (Bonestell LLC, 2018).

Figure 3.9: *Saturn as seen from Titan* by Chesley Bonestell, 1944 (Miller, 2013).

Bonestell's visions of space exploration depicted in books, magazines, posters and on television in the 1940's foreshadowed the future, as neither space exploration nor rocketry were a national priority at that time, nor would they be for some decades to come. Bonestell became known as a space expert and did everything within his ability to keep space in the national mindset. He lived long enough to see the space era emerge and humans land on the Moon.

3.1.5 Ralph Andrew Smith

Engineer, Artist, BIS President

Spacecraft engineer and artist for the British Interplanetary Society, Ralph Andrew Smith (1905-1959) had the polymathic ability and the unique opportunity of both illustrating and designing spacecraft. Certainly one might call Smith an Engineer's Artist, as he first proved that his spacecraft would be an engineering possibility before he it drew on paper. In 1938, Smith rendered and helped design the BIS Lunar Spaceship, a pioneering crewed spaceship study that laid the groundwork for subsequent studies (Parkinson, 2008).

Figure 3.10: Ralph Andrew Smith, (Parkinson, 2008).

As Smith developed into a leading draftsman for rockets, he was able to share ideas with BIS member, astronomer and writer Arthur C. Clarke, and engineer Harold Ross. The Smith-Ross Space Station, named after them, was a collaboration in 1948. It was envisaged with a mirror to capture solar energy, a spin to provide gravity, and a crew of 24 people (Shinabery, 2012).

In 1956-57 Smith assumed the role of President of BIS, and in 2007 he posthumously received the Lucien Rudaux Prize and was inducted into the Hall of Fame by the IAAA in recognition of the pioneering importance of his artwork.

These five people represent only a portion of those polymathic individuals who are responsible for setting the foundation for Astronomical Art to flourish and further integrate space arts' impact on space science.

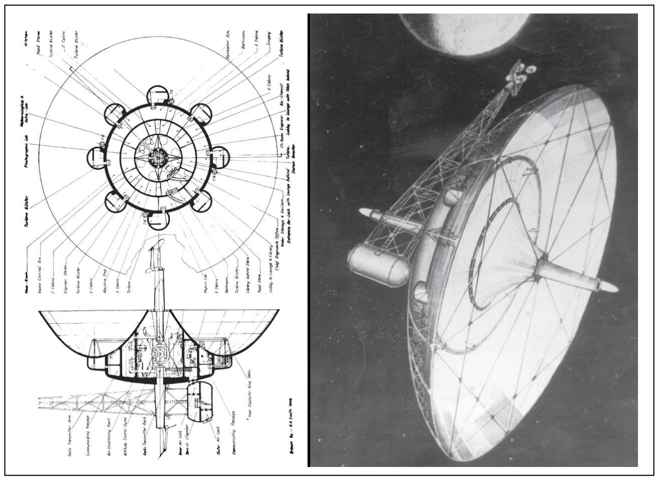


Figure 3.11: The Smith-Ross Space Station, 1948 (Parkinson, 2008).

Figure 3.12: The BIS Lunar Spaceship, 1938 (Parkinson, 2008).

3.2 Amaze, Inspire, Instruct: The purpose of space art

It is well documented how the art of space has amazed, inspired and instructed many a scientist, engineer, writer, filmmaker and artist of yesteryear. Also those in the present and most likely those of the future. But one wonders how so? Space Art itself has been discussed for more than six decades. It is a subject about which generations of artists and scientists have had and still hold strong opinions. What are the actual functions of space art in relation to science?

The purpose of space art is a subject that Professor Roger Malina, physicist, astronomer and executive editor of Art/Sci/Tech journal *Leonardo*, knows well and is passionate about:

> *"The space age was possible because for centuries the cultural imagination was fed by artists, writers and musicians who dreamed of human activities in space. Now with the end of the cold war the role of artists and writers is again crucial in defining our future vision of space and will once again be instrumental in incorporating the facts and discoveries of the space age into the cultural imagination."*
> - Roger Malina (Wilson, 2002)

3.3 Categories of Space Art

Space art categories are based on where the viewer would be observing from, and what senses would be used in such an undertaking. The three overarching categories of visual fine arts in the space age, as first defined by Frank Malina five decades ago, still remain relevant:

- Art made on Earth with new materials developed by astronautical technology, space flight and exploration
- Art made on Earth to express new psychological experiences or philosophical concepts about the universe resulting from space activity
- Art made on and used on the Moon and other planets (Malina, 1970).

As ideas for space art projects are vast in scope and phenomenal in number, those categories have been further sub-divided. In this dissertation, the author features six.

3.3.1 Art that depicts space hardware and/or spaceflight

Much of the artwork of the polymathic pioneers previously mentioned such as Nasmyth, Bolton, Rudaux, Bonestell and Smith would apply to this category. The genre was enhanced by present-day artists whose work span the publication field from trade magazines, books, newspapers, online journals, educational and commercial entities, and space agency outputs. Others continue the legacy of Chesley Bonestell by contributing their artistic skills to television, documentaries and film (Woods, 2019*a*). All print and media platforms have become the way new discoveries are introduced to the world.

3.3.2 Art designed for the outer space environment

3.3.2.1 The Moon

The Moon is the closest neighbouring celestial body and most obvious choice for placing an artwork, and the USA's crewed Apollo Moon landing missions presented the perfect opportunity to realize that goal. In 1969, *The Moon Museum*, an iridium-plated ceramic chip (the size of a postage stamp) on which American artists Robert Rauschenberg, Andy Warhol, Claus Oldenberg, John Chamberlain, Forrest Myers and David Novros drew simplistic designs, was covertly hidden in the gold insulation blankets on the leg of the landing module and left on the Moon during Apollo 12.

An infinitely more complex idea is one that Carnegie Mellon University is scheduled to send aboard their Astrobotic lunar lander in 2021. The project, entitled *MoonArk*, is designed to function as a tiny museum of Earth life containing data, images, and physical evidence of art, architecture, design, music, ballet, poetry, and drama (Carnegie Mellon University, 2015).

With artist Lowry Burgess leading teams of artists, designers, scholars, researchers, scientists, photographers, educators, technologists, and curators over the course of nine years, *The Moon Art Ark* is a collaborative sculpture with disks that integrate the arts, humanities, sciences and technologies. The artists and the museum plan for the Art Ark to remain operational for millions of years, and continue to project its message using deep space radio wave transmissions" (Cascone, 2015).

(a) (b)

Figure 3.13: (a) Moon Ark Project, 2015; (b) Moon Ark Art Disk, 2015 (Cascone, 2015).

3.3.2.2 Art On Spacecraft

Pioneer 10 (1972) and Pioneer 11 (1973) were equipped with plaques upon which physical and symbolic messages were inscribed, depicting the time, place of origin and location of Earth in relation to the galaxy, and line drawings of male and female human beings. Astronomer Carl Sagan's design concept was to indicate to extra-terrestrials that came across the spacecraft who made it and where it was from, so that contact would be possible (Rosenthal, 2016).

(a) (b)

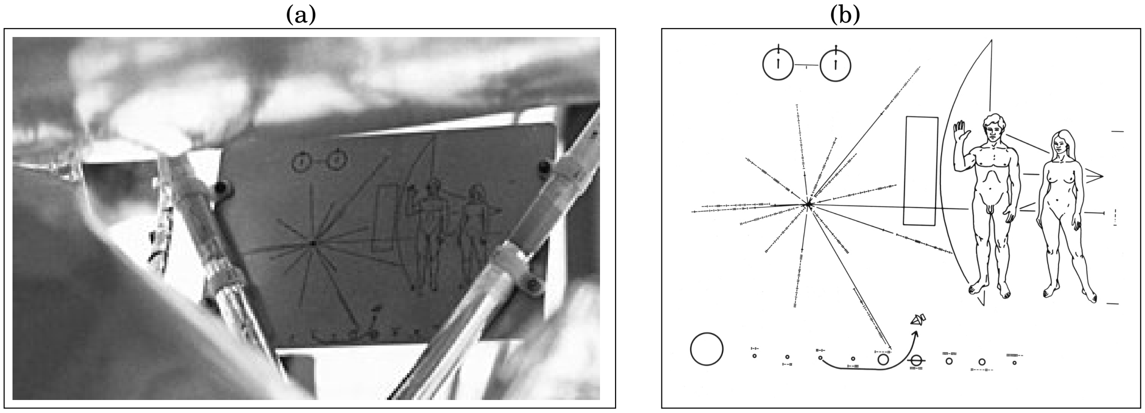


Figure 3.14: (a) A view of where the plaque was placed on Pioneer 10; (b) The visual message on the Pioneer Plaque (Rosenthal, 2016).

Voyager 1 (Sep 1977) and 2 (Aug 1977) both carried a time capsule intended to communicate a story of Earth to extra-terrestrials in the form of a 12-inch (30 cm) gold plated copper disk/ phonograph and its plaque. The recordings contain sounds and images selected to portray the diversity of life and culture on Earth. The contents of the record were selected for NASA by a committee chaired by Carl Sagan of Cornell University and his associates.

The records contain 115 images and a variety of natural sounds, and greetings in several languages. The cover is aluminum and electroplated upon it is an ultra-pure sample of the isotope uranium-238. Uranium-238 has a half-life of 4.468 billion years (JPL, 1977).

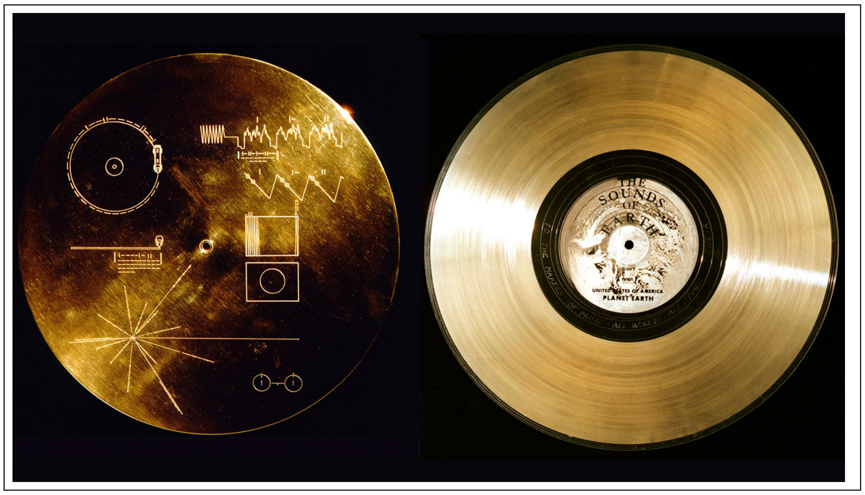


Figure 3.15: (Left) The Voyager Golden Record Cover with diagram; (Right) Voyager Golden Record 12 inch record of images and sounds of Earth(JPL, 1977).

3.3.2.3 Art on Titan and Mars

In 2005, the European Space Agency (ESA) included a CD containing messages and artworks on its *Huygens* space probe that landed on the surface of Saturn's moon Titan. In 2008, the DVD *Visions of Mars* containing science fiction stories and artworks about Mars arrived on Mars via NASA's Phoenix Lander.

3.3.2.4 Orbital Sculpture

Space is often viewed as a very large canvas or very large cinema screen, and a four-dimensional playground for artists as it lends itself to projections. The temptation is high to play with kinetics of light and movement. Sculptures placed in orbit are a highly controversial and highly contested form of space art that necessitates a global response, and responsibility. Many inventive proposals have been touted in the last few decades, using a range of materials. Some feature reflective mirror coatings and Mylar balloons, solar sails, reflecting balloons, inflatable toroidal sculptures, binary tethers, and spherical satellites.

The concepts also vary; some are designed as art for art's sake, others as educational opportunities, some to engage the public imagination, and others contain humanitarian messages of unity, such as the 1995 Star of Tolerance balloon by Frenchman Nersi Raazavi to publicize and popularize UNESCO's Year of Tolerance.

One recent success comes from the commercial sector. New Space launch company Rocket Lab launched *The Humanity Star* on 21 January 2018, despite the objections from astronomers. Shown in Fig. 3.16, Humanity Star was a carbon fiber geodesic satellite that reflected the sun's rays back to Earth was conceived as a visible prompt for the planet's population to consider/protect Earth's place in the universe. Viewers had the opportunity to track the satellite's location through its website for two months before it re-entered the Earth's atmosphere (Grush, 2018). Rocket Lab's CEO Peter Beck funded the space art satellite to call attention to a "one earth, one sky" concept. It also brought up the question of who owns the sky: the astronomers, the commercial sector, the political sector, the art sector or all of us?

Figure 3.16: *The Humanity Star* on Earth before launch (Grush, 2018).

The reception of the astronomical community to Trevor Paglen's *Orbital Reflector* was also mixed. Launched aboard a SpaceX rocket with 63 other CubeSats in December 2018, engineers lost touch with the satellite when the Federal Communications Commission (FCC) went silent during the government budget shutdown, and, subsequently, the engineers missed the window of opportunity to complete the deployment, and it can no longer be tracked.

Figure 3.17: A rendering of *Orbital Reflector* by Trevor Paglen (Paglen, 2016).

This sculpture exploded the Art/Sci dialogue as never before, with loud and long objections from the astronomical community, in anticipation of the sculpture's interference with imaging capability. Despite the outcry, Paglen, whose consultative team included space scientists and engineers, complied with all laws and received the project's FCC license. For Paglen, it has been a ten-year journey of designed provocation using Space Art as a catalyst for discussing the geopolitical militarization of Earth orbits, and the question of who directs the activities in the space commons. Paglen about the online war:

> *"My intention has been to bring some awareness about how profoundly compromised space has become by the world's militaries and corporations. I want people to ask questions about the legitimate uses of space. I want people to think about who should have the right to put what into space, and to what ends."*
> - Trevor Paglen (Paglen, 2018)

3.3.3 Art on Earth viewed from space

Visual art made on Earth with the aim of being viewed from space is artwork that is capable of being seen from the space stations or being sensed, measured, filmed and photographed by satellites.

The medium used in American conceptual artist/scientist, inventor/visionary Tom Van Sant's 1981 sculpture are mirrors and sunlight. Ninety 24-inch square mirrors were set at precisely calculated angles to accommodate the rotation of the Earth, the speed of the orbit

Figure 3.18: *Reflections from Earth*, Tom Van Sant, 1981. The one and a half mile wide sculpture was recorded by LANDSAT's multi-spectral scanner, traveling at 13,000 miles per hour (Thomson, 2015).

satellite and the position of the sun in the sky.

Tom van Sant's aligned reflective mirrors were undertaken as a symbol of hope, that a new dimension to human vision and a sense of scale could expand human being's concept of themselves and the universe of which they are part (Van Sant, 2019). The collaboration included Van Sant and scientists from the Stanford Research Institute, the US Geological Survey (USGS) and NASA. These land sculptures indicate the depth of space knowledge Van Sant had to obtain to produce the intended result, and how that knowledge influenced the style, design and intended purpose of the art.

3.3.4 Art viewed in space and in zero gravity

Space technology allows artists a new dimension to their practice - that of freedom from gravity, the ability to have artworks float, or to create art while floating. It is an intriguing phenomenon which has been greeted with enthusiasm from visual artists, musicians, and dancers.

Astro-artist Arthur Woods has designed and activated his sculptural art interventions aboard Mir and the ISS over the span of three decades. *Cosmic Dancer 1.0* was the first three-dimensional artwork to be specifically conceived for and officially realized in a space habitat.

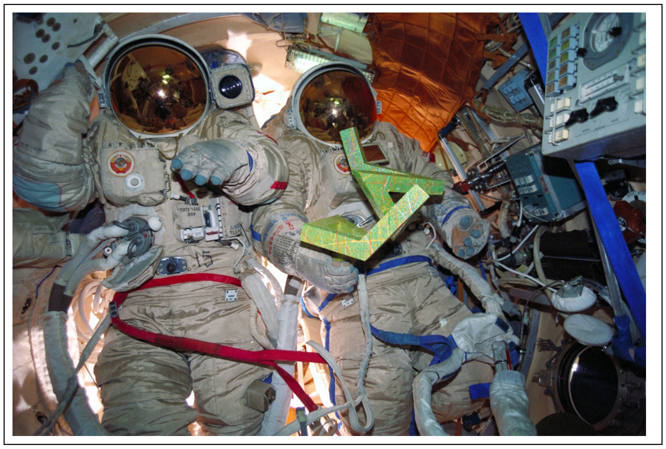


Figure 3.19: Arthur Woods *Cosmic Dancer* version 1.0, 1985 (Woods, 2019*a*).

Woods' overarching inquiry underpinning the project was to determine more closely what role art can play in minimizing isolation from Earth. Cosmonauts enjoyed the avantgarde shape of the angular green and speckle sculpture which inspired their imaginations to experiment with what they could do with it. As seen in their video, cosmonauts played with it, "danced" with it to music, and noted the colors of the sculpture were a comforting contrast opposed to their very technological and very high stress environment. The Cosmic Dancer was on-board when Mir deorbited into the Pacific Ocean in March 2001.

Cosmonaut Polischuk's response to *Cosmic Dancer 1.0* indicates that Woods succeeded in his purpose: to investigate the properties of sculpture in weightlessness, to explore the impact of sculpture in work and living spaces and to evaluate the process of integrating art into the human space program.

> *"We think that such art works are not only important to the artists who send them into space but also for us cosmonauts who simply feel the presence of a little artwork as comfortable. The rotating movement of the water in front of our sculpture is somehow perceived differently... from an emotional and aesthetic viewpoint. Sometimes it behaves like a living being, it swings and floats... and contemplating the sculpture turning in*

weightlessness while listening to music results in an effect which is possibly totally unknown on Earth."
- Alexander Polischuk (Polischuk, 1993)

If realized, the new and improved *Cosmic Dancer 2.0* will be created on board the International Space Station (ISS) as a 26^{th} anniversary commemoration of its ancestor, *Cosmic Dancer 1.0*. It is essentially a Do It Yourself (DIY) sculpture, which requires the astronauts to print the sculpture using the additive manufacturing facility on the ISS, assemble the three pieces correctly, and capture their interaction with it on film.

Figure 3.20: A 2018 photomanipulation to show the *Cosmic Dancer 2.0* as it is envisioned to appear aboard the ISS in 2019 (Woods, 2019*b*).

The production of art that is sent to space, completed on parabolic fights, on space stations or in orbit is only in its preliminary stages. One can expect much more complex and far more meaningful contributions in terms of an Art/Science purpose to be created as time, technology and funding will allow.

3.3.5 Art made in space

Astronauts have surrounded themselves with musical instruments on various occasions to participate in a communal production or a solo performance on the ISS, such as Commander Chris Hadfield's rendition of David Bowie's *Space Oddity*, filmed in 2013. The video was a collaboration with the Canadian public who selected the song choice for Hadfield (lead vocalist of the all-astronaut band Max Q), and the original artist, David Bowie, who not only gave his permission but also updated the lyrics and assisted with the legal ramifications.

Hadfield was happy to oblige the public, pay tribute to Apollo-era space exploration and to Bowie, as he felt that the emotional resonance of *Space Oddity* would be heightened when it was actually performed on a spaceship. To document the experience, Hadfield developed yet another polymathic skill, not only as a singer and guitarist, but that of videographer.

(a) (b)

Figure 3.21: (a) Still image of Hadfield in the Cupola from the *Space Oddity* music video, filmed aboard the ISS in 2013; (b) The sign that Hadfield put up on his sleep pod while he recorded the vocals. (Hadfield, 2013).

Hadfield filmed the scenes in the ISS during a one and a half hour scheduled downtime break. He manipulated the camera and lights as he filmed on various locations of the ISS, played guitar, and lipsynched to the lyrics he had prerecorded in his sleep pod. It became the first music video shot in space and has been viewed by upwards of 30 million people.

The Japan Aerospace Agency (JAXA), developed an Education Payload Observation mission to review the concept of culture aboard the ISS in 2012. The mission explored how sensory functions and conditions for conceiving "beauty" change in space. Two of the visual Art/Scientific experiments that were carried out on the Kibo station are discussed.

The Sakura experiment, shown in Fig. 3.23(a), was modeled on the flurry of Spring Sakura (cherry blossom) petals. Dyed silk petals floated inside a net while airflow was manipulated

Figure 3.22: A still of Chris Hadfield playing the guitar in one of the ISS modules in the music video for *Space Oddity*. The behind-the-scenes video with Hadfield's explanation of how he shot the video is available on YouTube (Hadfield, 2013).

with a paper hand fan. The movements were captured with a 3D camera by NASA astronaut Don Pettit. The experiments were aimed at moving Japanese culture into space, and having space influence new creativity into thinking about traditional Japanese culture (Murayama, 2012).

(a) (b)

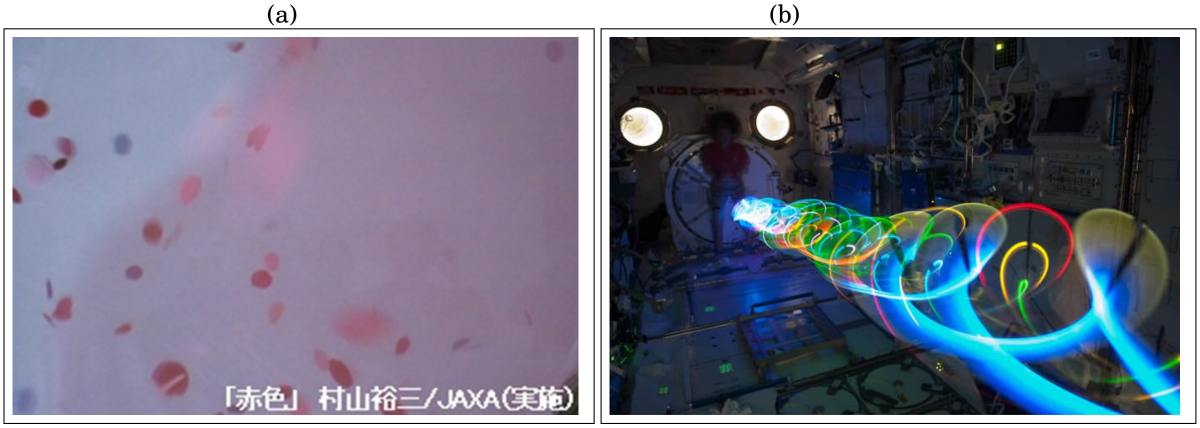


Figure 3.23: (a) Still image from the *Space Sakura* video, 2012 (Murayama, 2012); (b) The *Spiral Top* light experiment (Osaka, 2011).

Principal Investigator Takuro Osaka, from the University of Tsukuba, designed the Spiral Top experiment, a kinetic light sculpture utilizing modern art elements of dots, lines, and planes, as seen in Fig. 3.23(b). NASA astronaut Catherine Coleman activated the spinning top with LED lights and optical fibers that created an undulating aurora of planes and color of a steric light beam in a gravity-free state (Osaka, 2011).

3.3.6 Art using new space data

Many artists consult with astronauts, scientists, mission designers, and other experts to design their art, and avail themselves to all materials available from the largesse of space science. As the information age has eclipsed the technological age, artists have become interested in artfully displaying that information, both for aesthetic appeal and for educational purposes. Especially significant is artwork that advocates problem solving solutions regarding looming disasters brought about by technology, such as space debris. Collaborations between arts and sciences are on a scale of simple to complex, depending on the goal. The following example includes a collaboration between artists and scientists to bring satellite technology into the public consciousness and daily routine of life, and design the satellite as a work of art.

3.3.6.1 ARTSAT-1: INVADER and ARTSAT-2: DESPATCH

A collaboration between artists and scientists at Tama Art University in Tokyo and the University of Tokyo produced ArtSat-1: INVADER, which stands for *INteractiVe satellite for Art and Design Experimental Research*, the world's first media art satellite, which was launched on February 29, 2014, on a Japanese H-IIA F23 launch vehicle into a low Earth orbit. Its artistic mission was to produce media that connects Earth with outer space via images, voice and amateur radio.

The INVADER array of artistic output included algorithmic generation, and transmission of synthesized voice, music and poetry, capturing and transmitting image data; and communicating with the ground through a chatbot program. INVADER was operated by commands from the main ground station at Tama Art University. INVADER was a 1U-CubeSat with a mass of 1.85 kg (Kubota, 2014).

INVADER was equipped with a low-resolution camera (150 x 150 pixels), sensors to control lighting equipment, which changed color according to the satellite's temperature data, an amateur radio, and a Digi-Talker, to transmit voice data using FM and to transmit sensor data (Krebs, 2014). INVADER became the world's first media installation deploying data from an operating satellite, as a participant in the Mission SPACE x ART-beyond Cosmologies

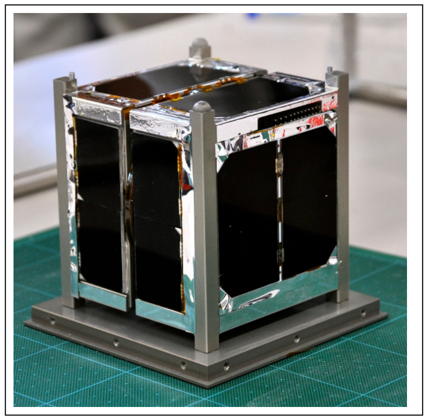


Figure 3.24: The ArtSat-1 INVADER cubesat (Kubota, 2014).

exhibition at the Museum of Contemporary Art in Tokyo from 7 June - 31 August 2014 before it deorbited a few days later on 2 September 2014.

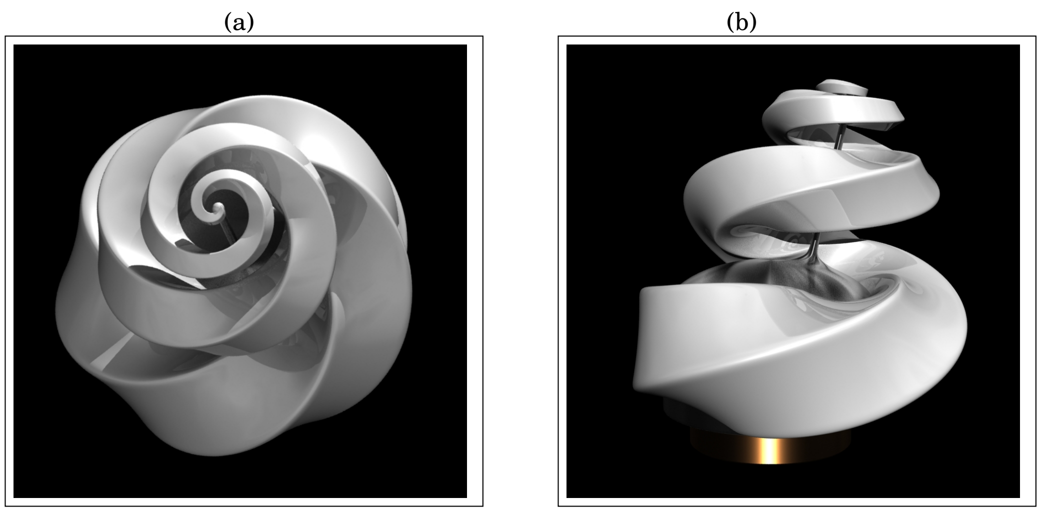


Figure 3.25: (a) top view and (b) side view computer simulated renderings of the *DESPATCH* sculpture (ARTSAT, 2014).

Following on from ArtSat-1, artists and engineers from Tama Art University and the University of Tokyo also produced ArtSat-2: Deep Space Amateur Troubadour's Challenge (DESPATCH), made of the first 3D printed satellite parts conceived as a space vehicle and a sculpture.

This nano-sculpture measures 50 by 50 by 45 centimeters in size and has a mass of approximately 30 kilograms. The radio operates at an amateur UHF frequency of 437 MHz, transmitting "poetic messages" from space using its own telemetry parameters such as voltage and temperature in a tele-creation process.

> *"The art satellite has no specific mission such as scientific exploration or engineering demonstration. We hope to introduce an awareness of satellites and the universe into our lives by creating media art works, that appeal to human perception and sensation using familiar data transmitted from the satellite such as temperature, brightness, and attitude"*
> - Akihiro Kubota (Halterman, 2015)

Figure 3.26: Students demonstrate the receiving antenna and equipment for DESPATCH radio signals (ARTSAT, 2014).

DESPATCH ended its operation on 3 January 2015, its last transmission from a distance of about 12 times the distance to the Moon, setting the new world distance record for a signal received by an amateur radio station.

3.4 Functions of Space Art

In 1990, planetary scientist and astronomical artist William K Hartmann examined the categories of space art and described four functions for it. The first is to encourage the interactions between science and exploration so that society can comprehend and conserve the beauty of the universe.

It's a big ask, but artists are up to the task, as evidenced by the prodigious amount of work illustrating comics, magazines, and books since Jules Verne's first publication in 1865, as well as posters advertising science fiction movies. All of these required illustration, thereby providing artists with a platform for their work, and an opportunity for generations of readers and movie goers to be engaged with the concept of space exploration.

(a) (b)

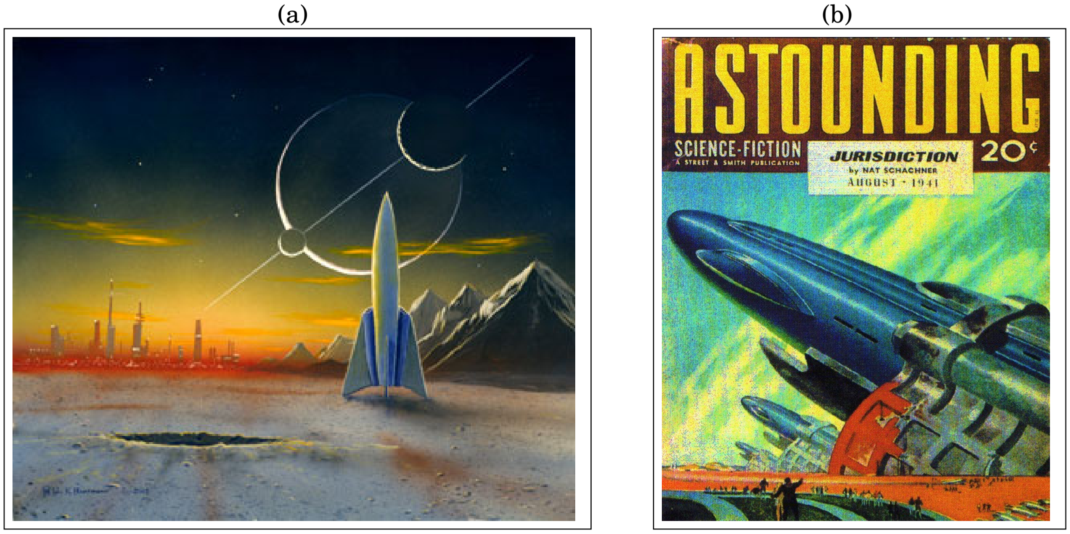


Figure 3.27: (a) *Homage to Classic Science Fiction* by William Hartmann, 2002 (Hartmann, 2002); (b) Cover Art by Hubert Rogers for the August 1941 edition of *Astounding Science Fiction* magazine (Rogers, 1941).

In his 2002 *Homage to Classic Science Fiction* of the 1950's (shown in Fig.3.27(a)), Hartmann salutes the pioneers whose paintings were used in science fiction publications. Fig. 3.27(b) illustrates the power and force of technology in space, using a shock and awe approach (Hartmann and Sokolov, 1990).

The second function relates to artwork providing an archive of the historical evolution of space exploration by the recording of actual events, and also recording the scientific thinking of the day. Scientific knowledge changes often as technology takes more accurate images and the data from sensing becomes more varied. A camera can also capture a scene and record history in the making, but the history that art can document has a far larger scope of describing the mood and human response to the moment. Traditional art methods also have the ability to later adjust the image to suit, the ability to paint something in or paint something out of an image, which a photograph, in and of itself, lacks.

A concept artist for the entertainment industry, Robert McCall worked on *2001: A Space Odyssey*, on *Astounding Science Fiction* (August 1941, Volume 27, No. 6), on the *Star Trek* movies, and on Disney's *Black Hole*. He spent 35 years as a visual historian for NASA, documenting its emotional history and collecting memories. His 1974 painting *Apollo-Soyuz Linkup* (shown in Fig. 3.28), captures the epic moment when former enemies became allies in space, when there were no cameras in sight to record the event.

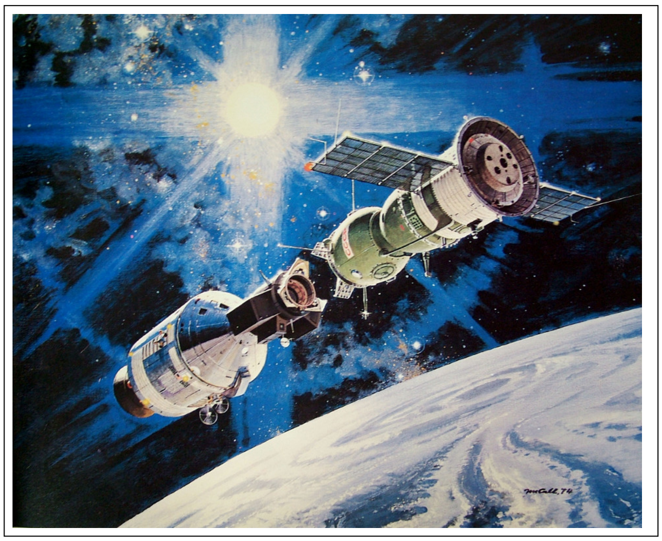


Figure 3.28: *Apollo-Soyuz Linkup* by Robert McCall, 1974 (McCall, 1974).

The third role of space art concerns the use of arts as an initiative to bridge political divides by nudging the international community towards common goals, joint ventures and future collaborations. As a matter of practicality, the timeline of artists working together to install a joint exhibition is much faster than any governmental bureaucracy could accommodate, and exhibitions draw society towards contemplating a new, different and hopefully better future.

The fourth role is to connect art and science in a practical working sense by comparing notes and discussing the physics shown in paintings, with artists playing a more direct role in scientific research by designing ways to present information, to communicate with other scientists, and to stimulate scientific visualization to inspire new ideas (Hartmann and Sokolov, 1990).

From time immemorial, before the written word and recorded history, artists have exhibited the presence of mind to chronicle celestial events and their consequence on human life. Art's inspirational and aspirational effect has breathed life into the imaginations and the careers of many an astronaut, scientist and engineer. One of the most important functions of 21st century space art is to serve as an ambassador for space science and technology, and to provide leadership and collaborative support in the advocacy for societal change.

Chapter 4

The Polymathic Art/Sci Phenomenon

This chapter explores the contributions of modern-day artists who are also scientists or inventors, and astronauts with experience of having flown in space who also practice art. The data collected serve to demystify both disciplines, that of science being too complex and obtuse for artists to understand, and that of artists having a stranglehold on aesthetics and beauty.

Following are three examples of artists reaching stardom in the performing and visual arts who also were equally talented in pursuing their technological proclivities. Actress/Engineer Hedy Lamarr, Visual Artist/Inventor Tom Van Sant and Musician/Astrophysicist Brian May illustrate artists as scientists.

The second part of this chapter explores the lives of seven astronauts from the USSR and the USA who have flown in space and are driven to create art about space. They are painters Alexis Leonov, Alan Bean, Michael Collins, Vladimir Dzhanibekov, Ron Garan, Nicole Stott, and photographer Story Musgrave.

4.1 Hedwig Eva Keisler - "Hedy Lamarr"

Inventor, Engineer, Movie Star
Austrian American actress and pianist Hedy Lamarr (1914-2000) was a Glamour Girl and movie star during Hollywood's "Golden Age" in the 1940's. Although a high school dropout at age 16, a mere decade later she became an inventor of note.

Figure 4.1: Portrait of Hedy Lamarr circa 1940 (CMG Worldwide, 2019).

Motivated by the USA's entrance into World War II and her Jewish heritage, she invented an encrypted radio system for frequency hopping to prevent the Allies' remote controlled torpedoes from being jammed by German U-boats.

Hedy's idea for frequency hopping occurred to her as she was playing a duet on piano. Her "Secret Communication System" was implemented by her friend, endocrinologist and music composer George Antheil based on the punched scroll used in player pianos. Filing Patent No. 2,292,387 on 11 August 1942, under her married name of Hedy Kiesler Markey, Hedy answered the call for inventions to assist with the war effort, and donated the patent to the US government (Rhodes, 2012).

Lamarr and George Antheil submitted their design to the National Inventors Council, and although it was enthusiastically received by some engineers in the Navy, it was not well understood by the Council who subsequently turned it down as being too bulky, and it was not used during that war. While the technology of the time prevented the feasibility of the idea at first, with the advent of the transistor and its later downsizing, the design became

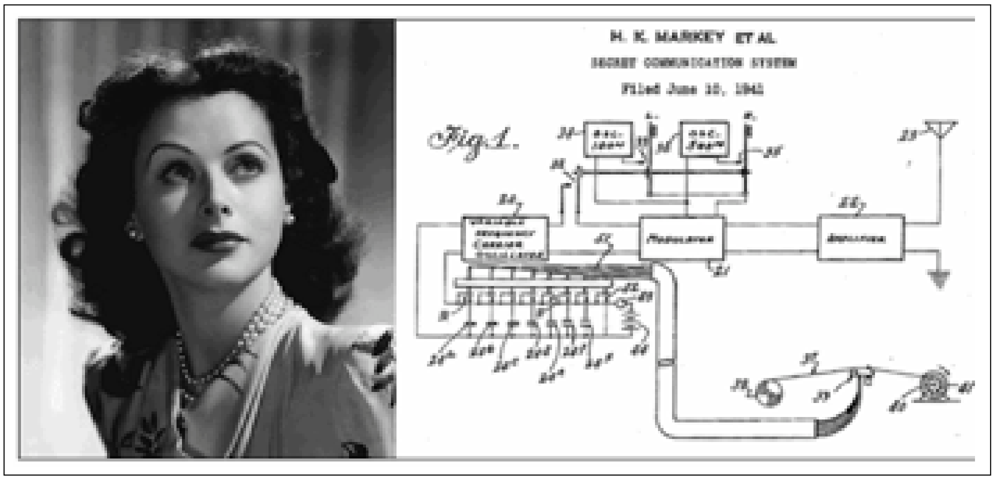


Figure 4.2: (Left) Hedy Lamarr studio headshot circa 1940; (Right) *Secret Communication System* patent diagram, 1942 (CMG Worldwide, 2019).

feasible to implement (CMG Worldwide, 2019).

Because her proposal was classified top secret, it remained locked up in the US Navy filing cabinet. However, in 1950's, before the patent was due to expire in 1959, a private company working on a US Navy project developing wireless technology was given access to the neglected concept and proceeded to design a communication system according to their plans (Rhodes, 2012).

In the 1960's the same engineer made further use of the spread spectrum technology as systems manager for a surveillance drone used to fly over Vietnam. Additionally, a radio communication system was ready and in place on the US Navy's amphibious force flagship Mount McKinley during the Cuban Missile Crisis in 1962, and the spread spectrum later became a solution for sequencing many simultaneous conversations on cellular phones (Rhodes, 2012).

Due to the expiration of the patent and Lamarr's being unaware of time limits for filing claims, she was never compensated for her invention, although the media had made it known she was the inventor. Her invention is used for WiFi, Bluetooth, GPS, and in top-secret military defense satellites. In today's currency, the estimate of the value of the invention is approximated at $30 billion (IMDb, 2019*b*).

Figure 4.3: Hedy Lamarr in her home laboratory, still image from the 2017 documentary movie *Bombshell*, directed by Alexandra Dean (Desta, 2017).

Lamarr also began working with pilot and aerospace engineer Howard Hughes, who offered his chemists and engineers to be at her disposal. In an interview she discusses her contribution to Hugh's aerospace empire:

> *"I thought the airplanes were too slow. I decided that's not right. They shouldn't be square, the wings. So, I bought a book of fish, and I bought a book of birds, and then used the fastest bird, connected it with the fastest fish. And I drew it together and showed it to Howard Hughes and then he said, 'You're a genius."*
> - Hedy Lamarr (Desta, 2017)

In 1997, fifty-five years after her spread spectrum patent, Lamarr was recognized as a Special Pioneer by the Electronic Frontier Foundation (EFF). Lamarr and George Antheil were also posthumously inducted into the National Inventors Hall of Fame in 2014. Lamarr's glamorous on-screen persona may have masked her technological achievements, but her polymathic abilities in the creative arts and engineering made her one of the most intelligent women in the movie industry, and in the engineering field as well (Rhodes, 2012).

Figure 4.4: A still image from the Hedy Lamarr Google Doodle animation on 8 November 2015. Lamarr also improved the design of traffic lights, which was referenced in the Google Doodle, celebrating her 101st birthday (Burton, 2015).

4.2 Tom Van Sant

Visual Artist, Inventor, Scientist

Tom Van Sant's professional work over seven decades includes visual arts, architectural design, city planning, art education, cartography and advanced technical inventions. He has executed over seventy major sculpture and mural commissions for public spaces around the world. A painter, sculptor, and conceptual artist, he received a Bachelor of Arts (BA) from Stanford University (1953), and a Master of Fine Arts (MFA) from Otis College of Art and Design in Los Angeles (1957). Tom grew up in an artistic family and has always known about his polymathic ability in the arts and the sciences. In a 2008 alumni interview with Otis College students, Van Sant explains his version of balancing the polymathic instincts:

> *"I am not sure how I am able to combine arts and sciences with the same level of interest, as each of those activities is supposed to come from a different side of one's brain. So, I guess I have to plead guilty to having the two sides of my brain connected and I can't be responsible for that. I will just express my gratitude because it's made a very enriched life for me to be able to bring these together in my work."*
>
> \- Tom Van Sant (Otis College, 2008)

Van Sant's space-related conceptual art projects began in the 1980's and led to the creation of the first satellite composite map of Earth. In a one-year collaboration with JPL scientist

(a) (b)

Figure 4.5: (a) Tom Van Sant, *Dolphin Wall*, sculpted concrete in Newport Beach, California, USA, 2001; (b) Close up of *Dolphin Wall* (Van Sant, 2019).

Van Warren, grant funding from NASA and the use of a supercomputer, Van Sant and his team stitched together 3,000 satellite images taken over a three-year period to produce a cloud-free, true-color view of Earth, as shown in Fig. 4.6. The 1990 *Geosphere Image* has subsequently been published in hundreds of magazines and atlases and has become the most widely distributed image of the world in the world. It is considered to be the cartographic event of the modern era (Van Sant, 2019).

Figure 4.6: Tom Van Sant's cloud-free *Geosphere Image* is total of 933.12 million true color pixels, where the width of one pixel at the equator represents a one kilometer-wide region (Van Sant, 2019).

The *Earth from Space* image was further developed into Van Sant's *Geosphere Project*, an educational platform consisting of a six-foot globe that incorporates exterior projection through fibre optics and variable light sources to enhance the understanding of Earth's processes and resources (Van Sant, 2019).

The Geosphere Image, the Geosphere Globe, and the Global Visual Library are components of the *Earth Situation Room* (ESR). The ESR is designed to serve as a worldwide network of installations; an integrated, interactive, multi-user system which serves as a clearing house, research center, and interface for worldwide research on global change and Earth resource management, and center for tracking and visualizing topical events of global concern. Seven interconnected "Earth Situation" rooms are installed in science centers worldwide (Otis College, 2008).

Figure 4.7: Tom Van Sant's Earth Situation Room 1992, at the Vattenfall/Liseberg Theme Park in Gothenburg, Sweden (Van Sant, 2019).

In 1983, nearly two decades prior to Google Earth's worldwide coverage, Van Sant used satellite imagery to progressively "zoom in" to images of Earth from space to the ground, using a 48-mirror array entitled *Eyes on Earth*. *Eyes on Earth* started with images from the geostationary GOES-6 Satellite 22,000 miles from Earth, continued through LANDSAT images orbiting 500 miles above the Earth, then aerial photography 20,000 and 5,000 feet above the Earth, and lastly handheld photography on the ground before the zoom culminated in a child's eye who was standing on the ground.

After a fast edit to create a video, the images were projected in near real-time at a conference in Los Angeles in conjunction with presentations given by Albert Hibbs of NASA JPL, and Richard Feynman of CalTech (Van Sant, 2019). One can only imagine how awe inspiring it was to the conference participants "back in the day."

Figure 4.8: Tom Van Sant (Left) with his friend, physicist Richard Feynman (Right), circa 1983 (Van Sant, 2019).

Van Sant developed a friendship with, and became the art instructor of, Richard Feynman (see Figure 4.8), with whom he collaborated to create the smallest human-made image. Using calculations provided by Feynman and Cornell University's scanning electron microscope, *Ryan's Eye* (shown in Fig. 4.9(a)) was etched into a crystal of salt using an ultra-small focused electron beam $\frac{1}{4}$ of a micron across on a scale 100,000 times smaller than the human eye can detect.

As a demonstration in extremes of scale, *Ryan's Eye* (Fig. 4.9(a)) is a companion piece to *Reflections from Earth* (see Fig. 4.9(b)), a mirror sculpture in the shape of an eye designed to be seen from space by Earth observation satellites. These are the largest and smallest images made to date, the larger being ten billion times the size of the smaller (Van Sant, 2019).

In terms of artistic and scientific collaboration, one meaningful example of environmental content, art and media merging for the benefit of society is the making of the documentary film *An Inconvenient Truth* in 2006, which professionalized Al Gore's original slide presentation. Director Davis Guggenheim heightened the appeal of the information by using sophisticated

(a) (b)

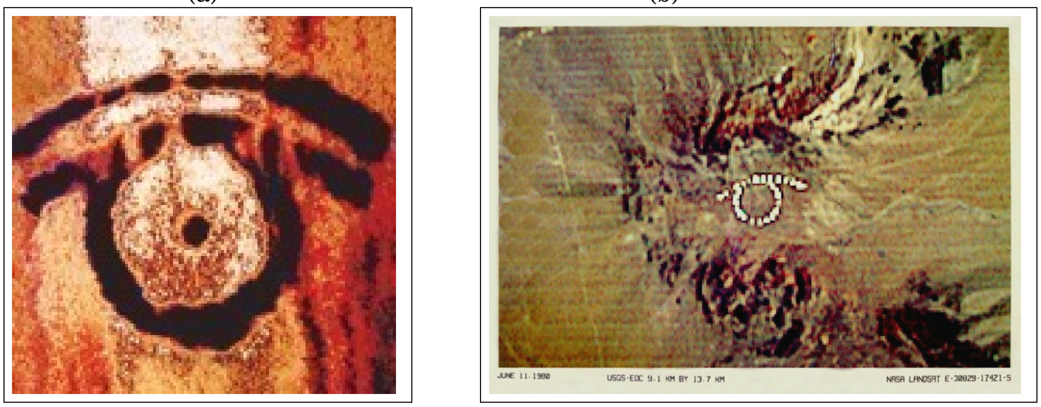


Figure 4.9: Tom Van Sant, (a) *Ryan's Eye*, the smallest human-made image, 1981; (b) *Reflections from Earth*, the largest human-made image, 1981 (Van Sant, 2019).

graphics which featured Van Sant's *Earth From Space* image. The documentary was financially successful and catapulted Gore's message around the globe. The film went on to win an Oscar and Al Gore went on to win a Nobel Prize. Van Sant's image went on to promote scientific education around the world via the GeoSphere project till this day. Van Sant's natural proclivity to create and invent in relation to his art gave rise to over a dozen technological inventions and patents (Van Sant, 2019).

To complete the picture of Van Sant's sphere of influence, he is a fellow of the MIT Centre for Advanced Visual Studies and a selection of his awards indicates the appreciation of both the arts and the science communities. Tom Van Sant's mastery over his divided interests represents the wide reach of his polymathic influence from the 1960's to present. His career demonstrates when one field overlaps the other, it is possible to achieve a balanced output in both fields, for the love of beauty, art, science and society.

4.3 Brian Harold May

Astrophysicist, Musician, Photographer

The accomplishments of the now seventy-something Brian May, CBE, Fellow of the Royal Astronomical Society and world renowned musician, exemplify that of a modern day "Renaissance Man" of the rock and roll generation. Driven by the twin passions of Science and Art, May has been able to excel in both. Born in 1947, in Hampton, Middlesex England, the guitarist, vocalist, and classically trained pianist left behind an academic life in astrophysics to become a founding member of the rock group *Queen*. Forty years later May was invited into NASA's New Horizons project as a science collaborator.

> *"I always had the twin passions. I was lucky I was able eventually to follow them both. I think we all realize ourselves best by opening up both sides of our intellect... artistic and scientific. It's really only the last couple of generations that forgot that! If you look at Copernicus, Fox-Talbot, Newton, even Einstein, you see this clearly — they saw no distinction between the two."*
>
> - Brian May (Simmons, 2016)

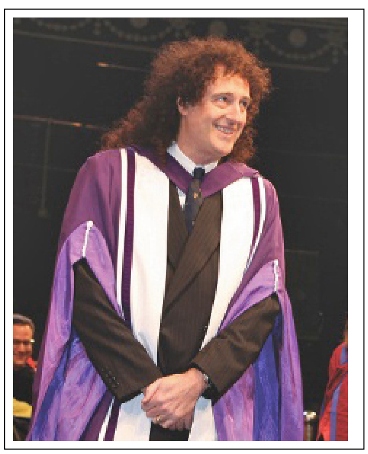


Figure 4.10: Brian May at his PhD graduation, Royal Albert Hall, London, 2008. His PhD investigated the radial velocity of zodiacal dust using absorption and doppler spectroscopy of zodiacal light by employing a Fabry-Pérot interferometer at the Teide Observatory in the Canary Islands (Imperial College London, 2012).

May studied physics and mathematics at Imperial College London, graduating with a BSc (Hons) degree in physics with Upper Second-Class Honours. The early 1970's found him immersed in his post graduate studies in the Infra-Red Astronomy department, aiming for a

PhD in astrophysics researching the velocity and direction of dust in the plane of the Solar System. In 1971 May made his first astronomical observations for his thesis and co-authored two peer-reviewed papers before being lured into show business.

Becoming a founding member of the rock band *Queen* in 1974, May developed into a renowned guitarist, songwriter, producer and performer. For thirty years, the list of accomplishments of *Queen* and May's subsequent musical career roll on and on, and are most easily appreciated by the fact that the band's 2018 biopic *Bohemian Rhapsody* was awarded 4 Oscars and has since played to an audience of approximately one billion, and counting.

May's life-long fascination with and participation in the field of astronomy is borne out in the books he has authored, his media appearances, and the attainment of a PhD (see Fig. 4.10) in astrophysics. In 2007, May handed in his PhD thesis, *A Survey of Radial Velocities in the Zodiacal Dust Cloud*. He graduated in 2008 from London's Imperial College (Imperial College London, 2012).

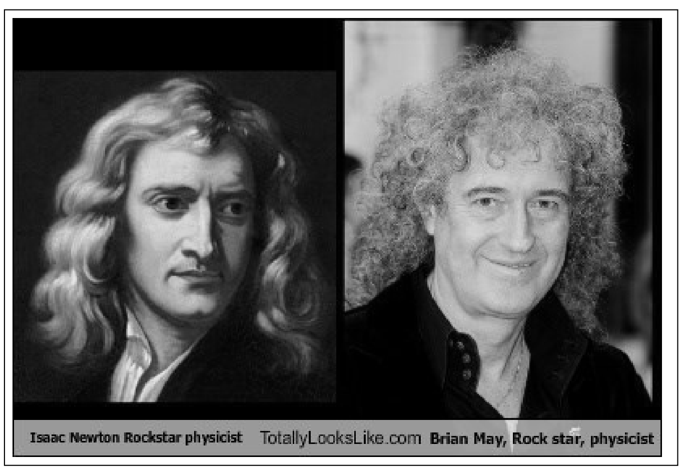


Figure 4.11: (Left) Isaac Newton; (Right) Brian May (Jmcenanly, 2015).

In addition to bearing an uncanny resemblance to astronomer Isaac Newton (1643-1727), shown in Fig. 4.11, May has another correlation with English history; his penchant for Victorian Era Stereoscopic 3D photography. An avid collector, he also redesigned and patented the stereoscopic viewer and invented the Owl VR Smartphone Kit, a virtual reality device that captures 360 degree videos (White, 2017).

The benefit of a stereoscopic view derives from using the characteristics of binocular vision to enhance the illusion of more depth, height and acuity to intensify surface detail. Through his London Stereoscopic Company, May has re-purposed the stereoscope as an astronomical device for use in the space age.

May was introduced as a science team collaborator at NASA's New Horizons Pluto flyby press conference on 17 July 2015. Using an image of Pluto taken on 15 July 2015 and another taken two days later, May was able to construct the first stereoscopic image of Pluto.

> *"I was obsessed with finding stereoscopic opportunities while I was there, because I was there when the first 2 by 2 mosaic full-planet picture was downloaded from the probe, and assembled into exactly the required high res partner to the iconic "last-look" photo which preceded the final fly-by. I was able to assemble the two images to make the most satisfying stereo view I can ever remember making, this is definitely the first REAL high quality stereo image of Pluto in history"*
> - Brian May (May, 2015)

Figure 4.12: A stereoscopic image of Brian May holding the first stereoscopic Pluto photograph (Cassidy, 2015).

Almost three years after New Horizons recorded the clearest images yet of Pluto, it reached minor planet 2014 MU69 (unofficially nicknamed "Ultima Thule"), the furthest object in our solar system ever visited by a spacecraft. On 31 December 2018, through 1 January 2019, May was in attendance at the watch party and performed an updated version of his New

Horizons anthem to human endeavor (Kaplan, 2018). May will continue to create images with the New Horizons team as the data is downloaded.

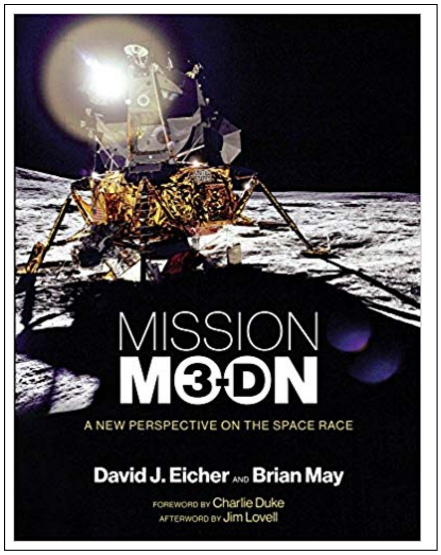


Figure 4.13: The *Mission Moon 3D* book cover by Brian May and David Eicher (Eicher and May, 2018).

In a notable NASA and Roscosmos collaboration, Brian May and David Eicher co-authored *Mission Moon 3-D: A New Perspective on the Space Race*, published by May's London Stereoscopic Company, whose extensive archival images depict the history of space flight to the Moon including the lunar landing. It was published in 2018 to honor the 50^{th} anniversary of the Moon landing in 1969.

4.4 Astronaut Artists

A particularly fascinating category of artist are those who have a life-long interest in and attraction to practice art, although their professional careers are astronautical.

In this chapter, the most artfully accomplished of the early astronauts, such as Alexei Leonov, Alan Bean, Story Musgrave, and Vladimir Dzhanibekov are highlighted for their passionate determination to express themselves and their space experiences through various media.

It is the deep-seated need to engage with both their artistic and scientific sides that speaks to the balance of their polymathic attributes, and that which the life of an astronaut brings to their art.

4.4.1 Alexei Arkhipovich Leonov

Cosmonaut, Artist, Author

Known for his convivial personality, generosity, and athleticism, Leonov (1934 - 2019) is yet another truly remarkable renaissance person straddling the 20^{th} and 21_{st} centuries.

"Space exploration and work in space must serve the people of the whole world. I feel obligated to share my vision of space with people by means of the art I have at my disposal."
- Alexei Leonov (IAAA, 2000)

Born in Siberia, Union of Soviet Socialist Republics (USSR), Leonov's propensity for art started receiving notice when he was eight years old. He was accepted to the Riga Academy of the Arts in 1953, but finances intervened and instead, he found himself enrolling in the Chuguyev Air Force School to start a career immersed in his second passion, flying, while also continuing art instruction. In 1960 he was selected as one of the first group of cosmonauts and became the first artist to draw in space, to film in space and the first person to walk in space and be able to paint the experience of his own spacewalk (ESA, 2007).

(a) (b)

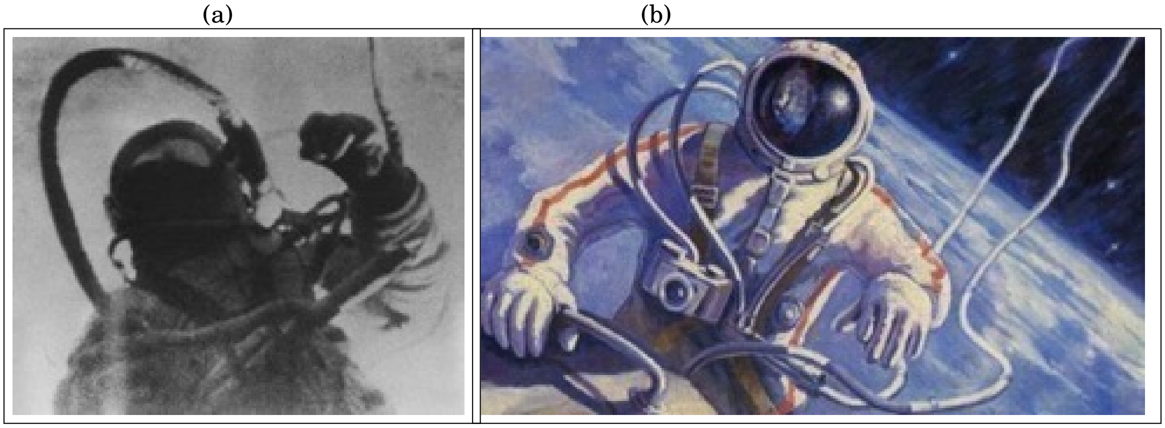


Figure 4.14: (a) Leonov was the first human to walk in space on Voskhod 2, 18 March 1965; (b) *In Open Space* by Alexei Leonov, oil on canvas (VintageTech, 2018).

During his historic flight in 1965, which included a death-defying spacewalk, a harrowing re-entry and rescue, Alexei found the presence of mind to sketch with supplies he had modified for work in zero gravity: paper and colored pencils (see Fig. 4.15(a)) with an elastic wrist band for the box and strings attached to each pencil for retrieval.

(a) (b)

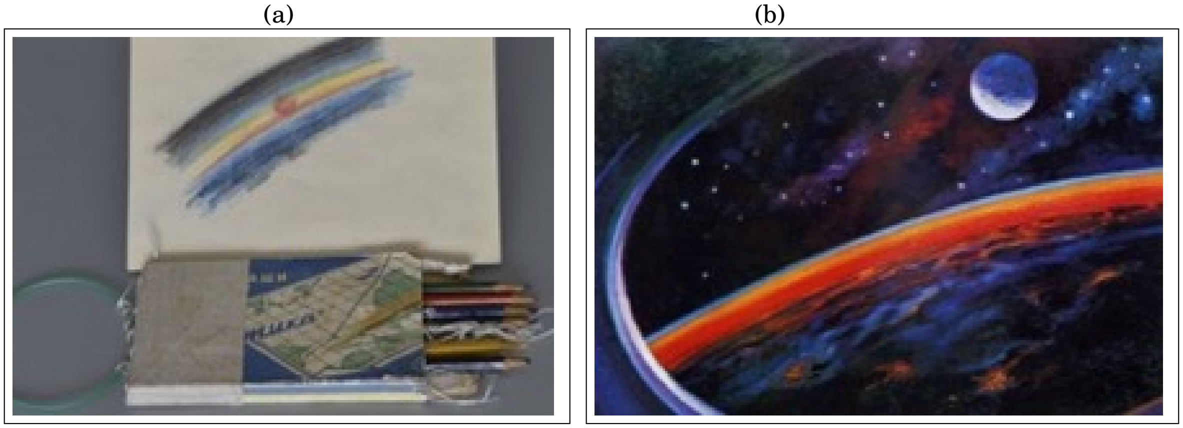


Figure 4.15: (a) Taktika pencils used by Alexei Leonov on board Voskhod 2 (1965), and the first *Sunrise Sketch* created in Space (Brown, 2015); (b) An oil painting by Leonov (VintageTech, 2018).

Figure 4.16: Alexei Leonov pictured in front of his painting *In Free Flow* depicting his spacewalk in front of Voskhod 2 (Roscosmos, 2016).

Leonov's artistic efforts over time have rendered him one of the best-known space artists. Leonov was elected a member of the Cosmic Group of the USSR Union of Artists. His paintings have been exhibited worldwide, his works have been published in space art books such as *In the Stream of Stars*, *Wait for Us*, and his own books. Honors for his art work include the

IAAA Lucien Rudaux Memorial Award and induction into the International Association of Astronomical Artists' Hall of Fame.

4.4.2 Alan Lavern Bean

Artist, Aviator, Astronaut

Alan Bean (1932-2018) was an artist, aviator, astronaut, 4^{th} person on the Moon, and the only artist to visit the Moon. He followed his creative imperative to study art hand-in-hand with his training as a test pilot and astronaut. Bean's development as a painter began with his first art class while he was a test pilot at Patuxent River, Maryland in 1956.

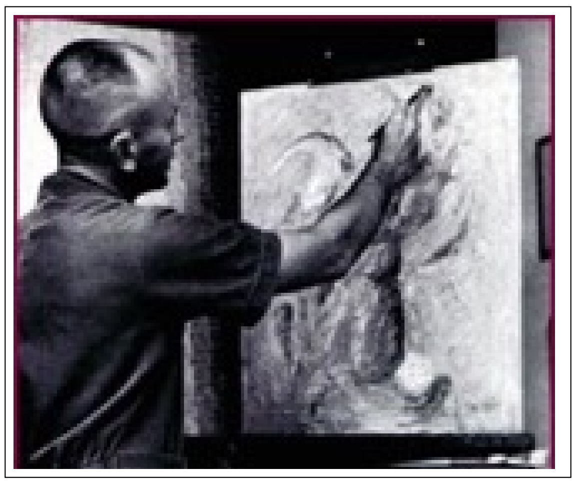


Figure 4.17: Alan Bean in studio learning his craft in 1964 (Lotzmann, 2019).

As a student, Bean studied paintings by Cezanne, Degas, and others, but he was most influenced by French impressionist Claude Monet (1840-1926), after whom Bean styled his own impressionistic interpretation for what would become a truly authentic perspective of the lunar landscape. Although Bean identified himself as an artist who was once an astronaut, Bean's career in space was as epic as the moments he portrayed in paint.

On 19 November 1969, Bean become the first artist to step on a lunar surface. In 1973, Bean made his second space flight as Commander of the Skylab II crew that spent a then record-breaking 59 days in Earth orbit and traveled 24,400 miles in space. For his remaining career in NASA, Bean worked with the Space Shuttle program,and was named acting Chief Astronaut. All the while, Bean continued to study painting. At age 49, after nearly two decades

Figure 4.18: *My First Step* by Alan Bean, 1985 (Bean, 1985).

as an astronaut, Bean resigned from NASA 1981 so that he could further document the Apollo era missions in his paintings, including his own first step on the Moon (see Fig. 4.18).

> *"I wonder how Claude Monet would have painted it. With him in mind I have not painted the Moon the neutral gray I saw with an astronaut geologist's eye, but rather a more beautiful combination of hues. I think Monet would approve."*
> - Alan Bean (Bean and Chaikin, 1998)

Bean's decision to retire from NASA to devote himself full-time to painting was based on his personally held obligation to capture the visions that no other artist had ever been able to see first-hand. Bean chose painting to capture the emotional atmosphere about being on the Moon. His strategy included inculcating Moon dust, material from his uniform, and Moon-boot footprints into his lunar paintings.

> *"Our generation will be remembered for many achievements, and one of the greatest will be our movement off the Earth, from its gravitational pull, to begin our future generations' exploration of the universe. My paintings record the beginnings of a quest never to end, our journey out among the stars."*
> - Alan Bean (Bean, 1985)

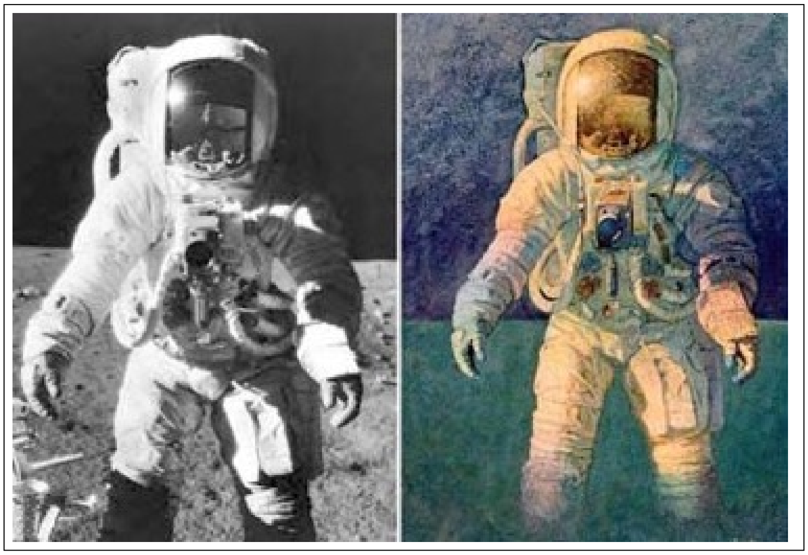


Figure 4.19: (Left) A photograph of Alan Bean on the Moon in November 1969; juxtaposed with (Right) Bean's favorite self-portrait *That's How It Felt To Walk On The Moon*, 1986 (Lotzmann, 2019).

Figure 4.20: Alan Bean in studio (Bean, 1985).

4.4.3 Franklin Story Musgrave

Trauma Surgeon, Astronaut, Photographer

Perhaps it can be said that Story Musgrave (see Fig. 4.21) is the epitome of what any one polymathic person can possibly embody in just one lifetime. A self-taught automotive mechanic and airplane enthusiast, Story took his solo flight at age 16, and after a stint in the US Marines, this high school drop-out soon began to devour knowledge.

Figure 4.21: Story Musgrave's 1997 NASA Astronaut Portrait (NASA, 1997).

Over the course of eight years from 1958 to 1966 he pursued a science degree in mathematics and statistics, a masters in operations analysis/computer programming, a BA in chemistry, a doctorate in medicine, and a master of science degree in physiology and biophysics. Later he also became a commercial pilot, a trauma surgeon, a lecturer, a poet and an avid photographer. The first astronaut to fly on six shuttle missions and the only astronaut to fly on all five space shuttle orbiters, Musgrave logged over 25 million miles in space.

In 1974 he began design work for the shuttle, including the space suits, air lock, and launch escape systems. He also helped design the Skylab space station, and devised systems and procedures for spacewalks. NASA's expert on spacewalks, Musgrave was the astronaut chosen in 2010 to lead the crew of engineers on STS 61, the first mission to save the Hubble telescope. Fig 4.22 depicts Musgrave anchored on the end of the Remote Manipulator System arm preparing to install protective covers on the magnetometers during the five space walks it took to repair the telescope, three of which were his.

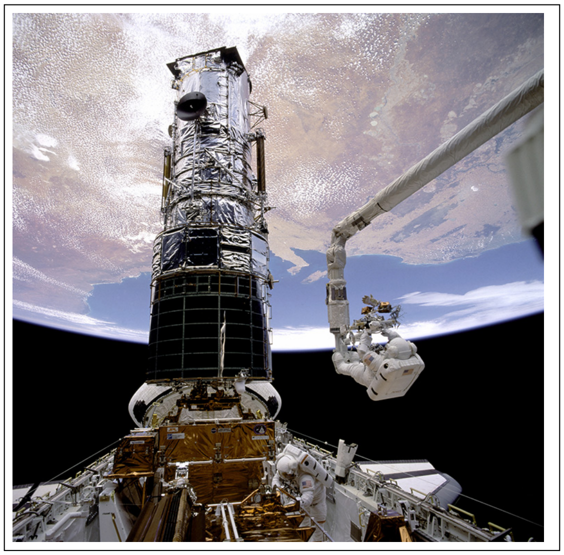


Figure 4.22: Story Musgrave performing repairs on the Hubble Space Telescope in 2010 (Chow, 2013).

Musgrave's life and times is a study in intergenerational space science and interdisciplinary endeavors. For example, within his career, Musgrave became good friends with both Wernher von Braun and Carl Sagan, bridging the gap between these legendary intergenerational space science figures. Story's biography relates the tale of the hours that Story and von Braun spent discussing the meaning of, and the future of, space, and includes Carl Sagan's quote that he and Story were, "souls from the same soup" (Lenehan, 2004).

Story transmigrated disciplines as well. His unique education and experience afforded him the opportunity to forge connections between aviation mechanics, artificial intelligence, neurophysiology, engineering, design, space flight, and the art of photography. That is what a good polymath does, and with a total of seven degrees, including one in literature, he is one of the best.

Whether in an aircraft, upside down in the T38, or in a spacecraft, Story went to considerable lengths to develop his photographic techniques using both Nikon and Hasselblad cameras during his spacewalks. To increase his proficiency he practiced using these cameras while traveling in T38 jets where the conditions are somewhat similar to those of spacewalking, in that one is hampered by wearing gloves and moving at a very high rate of speed (Lenehan, 2004).

Story practiced changing lenses and filters on various cameras thousands of times, so that in space it would be completely automatic - so as not to miss a great photo op, when time is of the essence, and there are no second takes. The long life and diverse interests of this octogenarian afforded him the platform to transmigrate disciplines. At 83 years of age as of this writing, Musgrave is unsurpassed in employing his photographs to dramatic effect and his zeal for space science.

(a) (b)

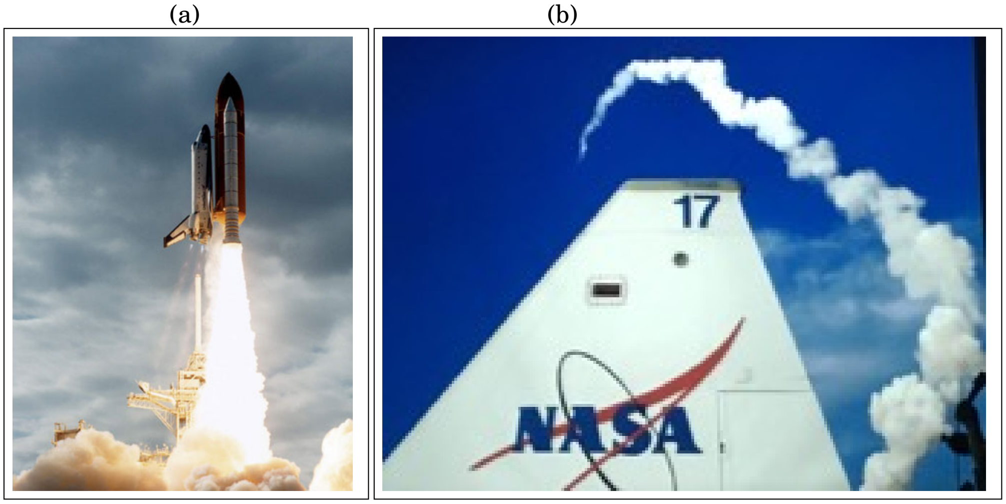


Figure 4.23: (a) Story Musgrave, *Space Shuttle Launch*, 2009 (b) A shuttle launches in an arc over the tail of a NASA T-38 jet, date unknown (Gould, 2019).

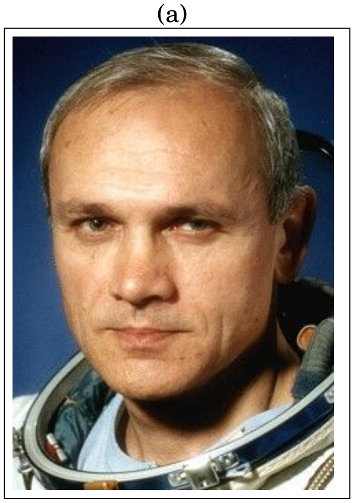
"I love art history. I love reading books on art history, you look at what is said in a picture. So I learned how to look out the window of a spaceship having read art history, the interpretation of it, I get in the spaceship window and I become an art historian, I treat what is out the window as a painting, as a work of art."
- Story Musgrave (Lenehan, 2004).

4.4.4 Vladimir Aleksandrovich Krysin Dzhanibekov

Cosmonaut, Artist

A native of Iskander/Tashkent, Uzbekistan, USSR, Vladimir Dzhanibekov began painting in childhood, studied art at the Komarov Higher Air Force School, and later physics and flying at Leningrad University. He became a cosmonaut in 1970 and distinguished himself as commander of five Soyuz missions from 1978 to 1985 during which time Dzhanibekov led an epic rescue of the powered down Salyut 7 space station (Astronautix, 2019).

(a)



(b)

Figure 4.24: (a) Vladimir Dzhanibekov's Cosmonaut Photo, 1970 (Astronautix, 2019); (b) An artwork of Dzhanibekov (front) and cosmonaut O. G Makarov was featured on a 1979 USSR Soyuz-27 Commemorative Stamp, with Salyut 6 in the background (Komlev, 1979).

Along with fellow cosmonaut Alexei Leonov, Dzhanibekov is a member of the famed Russian Artists Union and its Cosmic Group. In his artwork Dzhanibekov illustrates the psychological and philosophical side of the uniquely dangerous endeavor of spaceflight as indicated in Fig. 4.25(a). He celebrates the historic moments as well, as indicated in Fig. 4.25(b). These images are discussed below.

(a) (b)

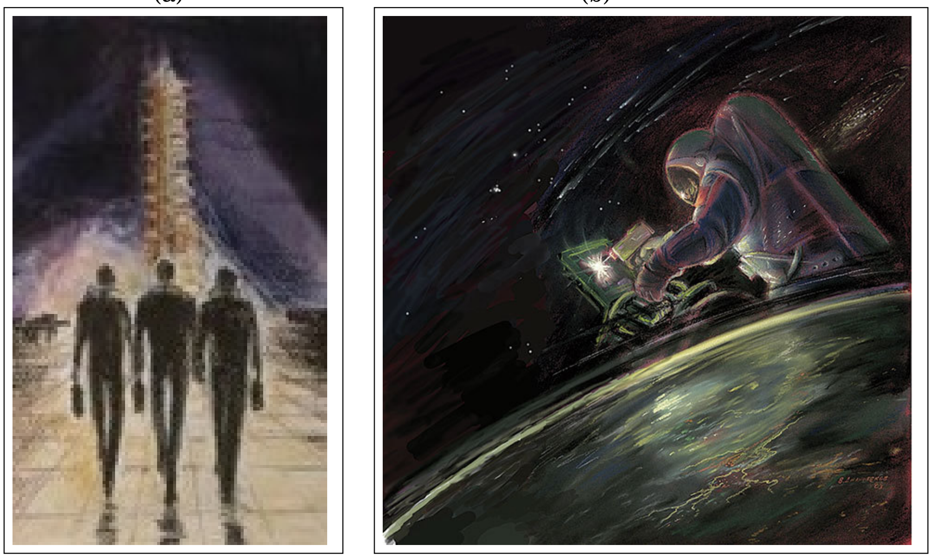


Figure 4.25: (a) Vladimir Dzhanibekov, *The Crew / Back to Work*, date unknown (Miller, 2014); (b) *Svetlana Savitskaya / Space Welding*, circa 2003 (Dzhanibekov, 2014).

The Crew / Back to Work (Fig. 4.25(a)), by Dzhanibekov depicts one of the most psychologically intense moments of a space journey. A time when human lives will be dependent on machines, and the moments of walking out to the rocket are intensely isolating, and call for introspection (Miller, 2014).

Svetlana Savitskaya / Space Welding (Fig. 4.25(b)) by Dzhanibekov captures the essence of the moment when his colleague Svetlana Savitskaya becomes the first woman to walk in space. She is depicted here conducting scientific tests on welding, soldering and cutting metals in space. A print of this painting resides in the Cosmonautics Museum in Moscow, the US National Air and Space Museum in Washington, D.C., and went aboard the ISS with cosmonaut Yuri Shargin in 2004 (Pearlman, 2005).

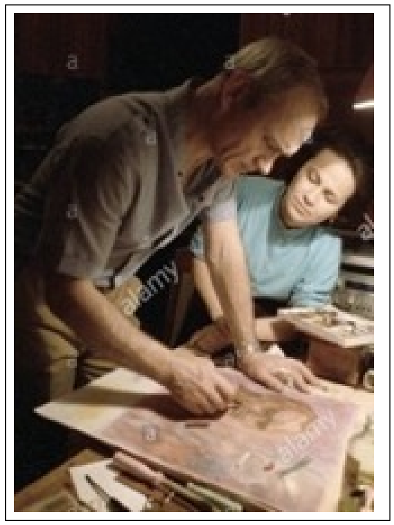


Figure 4.26: Dzhanibekov and his wife Lilia in his studio, 1 March 1987 (Alamy, 1987).

Three contemporary astronauts who are compelled to engage in the visual arts to express their experiences after space flight are Michael Collins, Ron Garan and Nicole Stott. Although they are not in the same category as professional artists or have experienced such acclaim for their art, as have the first four iconic astronauts, they use their status to express their experiences, to serve as ambassadors for space activity and space education.

4.4.5 Michael Collins

Astronaut, Author, Artist

Michael Collins' most famous mission was as pilot of the Apollo 11 Command Module in 1969. Collins became the first and only person thus far to orbit the far side of the Moon alone and out of communication with any living being while waiting to rendezvous with Armstrong and Aldrin. After leaving NASA in 1970, Collins authored four books about space, *Carrying the Fire*, *Liftoff*, *Mission to Mars*, and *Flying to the Moon*. He chose watercolors on paper as another avenue to further indulge his creative impulses.

Collins paints vignettes from nature, earthly subject matter, as well as the airplanes and jets he has flown, but rarely paints space subjects specifically, although the title Tranquillity Base II (Fig. 4.27(b)) refers back to the Moon mission (AstronautCentral, 2019). Now as an elder statesman of the Apollo era, Collins' passion for communicating comes through his opinion concerning socio-political and environmental truths that a view from beyond the Earth can offer:

> *"If the political leaders of the world could see their planet from a distance of 100,000 miles their outlook could be fundamentally changed," he said. "That all-important border would be invisible, that noisy argument silenced. The tiny globe would continue to turn, serenely ignoring its subdivisions, presenting a unified façade that would cry out for unified understanding, for homogeneous treatment. The Earth must become as it appears: blue and white, not capitalist or communist; blue and white, not rich or poor; blue and white, not envious or envied."*
>
> - Michael Collins (Collins, 2009)

(a) (b)

Figure 4.27: (a) The NASA Astronaut portrait of Michael Collins, 1969; (b) *Tranquility Base II* by Michael Collins, watercolour, date unknown (AstronautCentral, 2019).

4.4.6 Ron J Garan

Astronaut, Aerospace Engineer, Artist

Ron Garan feels a responsibility to share his perspective of the planet gained in space to as many people as possible through as many channels as possible. Authoring his acclaimed book *The Orbital Perspective* is one channel, another is through his over 4 million followers on social media.

Garan is included on Google+'s 25 most followed, and Kred's list of Top 1% influencers. Garan launched his website *Fragile Oasis* to interact with followers. Yet another, more personal avenue is through his painting (Garan, 2019).

(a)

(b)

Figure 4.28: (a) A photograph of Ron Garan during a 2011 spacewalk; (b) *Perpective* - Garan's "Selfie" is seen as his image is reflected off the visor of his colleague Mike Fossum as Garan snaps the shot. By avoiding only having one particular focal point in this painting, Garan communicates the experience of being bombarded with compelling images in a spacewalk, all competing for the astronaut's attention (Garan, 2019).

"I really believe that seeing our planet from that (space's) perspective can have a profound positive effect on the trajectory of our global society. To date we have taken pilots and engineers and scientists to space, imagine what will happen when we take artists and poets and musicians. How much better are they going to be with sharing this experience with the world"

- Ron Garan (Garan, 2019)

4.4.7 Nicole Marie Passonno Stott

Engineer, Astronaut, Artist

As an aeronautical engineer, Stott's NASA career began as a manager for the Space Shuttle and ISS programs at the Kennedy Space Centre in 1998. She subsequently served as crew and trained astronaut pilots to fly the Space Shuttle.

> *"I think the best engineers and scientists have a creative side too. And it is a creative side that they incorporate into their engineering and scientific work. I definitely use some aspects of engineering in my artwork. The integration of art and science just makes sense, especially from the standpoint of aesthetic design and communication of complex ideas or data. Problem solvers are creative and use their whole brain"*
>
> - Nicole Stott (Rosso, 2017)

(a) (b)

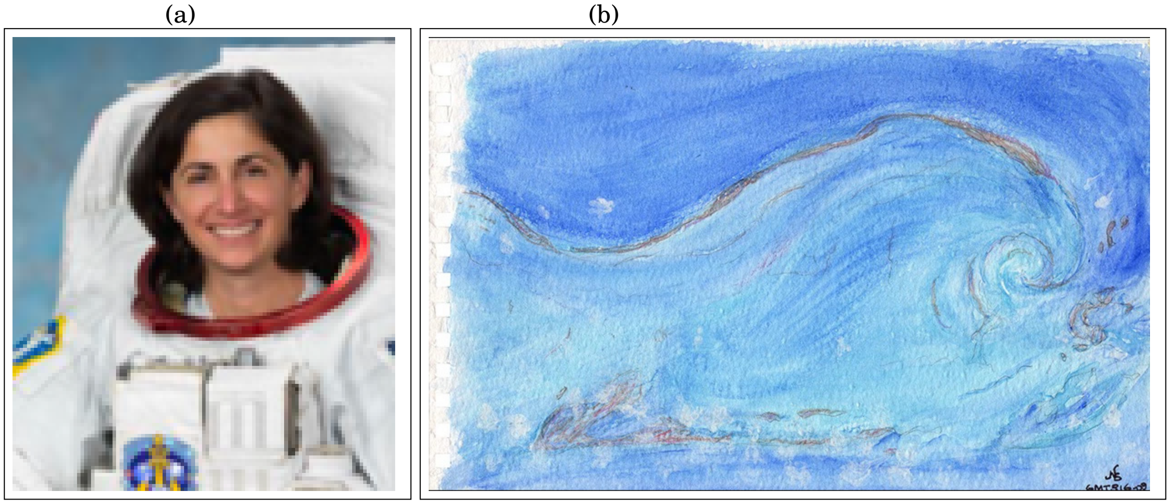


Figure 4.29: (a) Astronaut portrait of Nicole Stott (NASA, 2015); (b) *The Wave* by Nicole Stott, 2009 - the first watercolor painting done in space (Stott, 2019).

After retiring from NASA in 2015, Stott developed her ISS photographs into paintings and prints for a wide art audience that includes the craft market. Her images are printed onto night lights, tote bags, home décor, jewelry and handbags. She is a founder of the Space for Art Foundation, and a motivational speaker for the value of space science and space art (Stott, 2019).

4.5 The Overview Effect

Figure 4.30: *Earthrise* by Bill Anders, photographed on 24 December 1968 as they flew around the Moon on Apollo 8 (Anders, 1968).

The Earthrise photograph snapped by William Anders from lunar orbit on December 24, 1968, during the Apollo 8 mission sums up the cosmonautic phenomenon known as "The Overview Effect," a title coined by space writer Frank White in 1987, as he sought to explain why astronauts who saw the Earth from space spoke about the planet differently when they returned, as they tried to describe the mental shift of consciousness and of world view as they perceived the Earth as part of a larger whole, in relation to the universe (Guarino, 2015).

The astronauts mentioned in this dissertation all came back with a new-found activism which manifested in an enduring obligation to educate their colleagues, their country and the world at large about the urgency for maintaining a sustainable future for the Earth. Their overwhelming sense of majesty about the experience comes across in how they express space, Earth and the planets in their various art forms.

Additionally, the artists and scientists alike cited in this dissertation donate their celebrity status, their time and their income to further the aims of educational and environmental charities, and serve as mentors to the next generations of artists and scientists. Hedy Lamarr sought to save lives by donating her patent to help end WWII. Tom Van Sant donated his global map to educational entities worldwide. Brian May is a strong advocate for wildlife protection. Alexei Leonov donates the sale of some of his paintings to children's concerns. Alan Bean, Story Musgrave, Ron Garan, Michael Collins and Nicole Stott also donate a portion of their space painting proceeds to charities and fund educational and environmental initiatives. For the artists and scientists cited in this study, there seems to be an overarching need to contribute their polymathic abilities for the betterment of society driven by the epiphanies they experienced in space.

This chapter covers only a portion of the astronauts who have flown in space who are also involved in visual arts/social advocacy. Comparative data cannot reveal an exact percentage of space astronauts who practice visual art and/or social advocacy because the true numbers have not yet been tabulated. Nonetheless, one could posit that precisely because of the similarities in the traits of artists and scientists, a disproportionate number of scientists are indulging in the arts as a mechanism to express their new world view. Astronaut/artist numbers will increase exponentially as polymathic education and availability to fly in space increases. Further data on astronauts globally would be needed to yield a definitive percentage of how many that have flown in space are polymathic in the arts, and how many use their personal agency to preserve the planet because of the overview effect.

Chapter 5

Towards a Culture of Transdisciplinary Collaboration

The relationship between the disciplines of the arts and the sciences has been a topic of interest for many decades, but in the Space Age this interaction has demanded a progressively more complex interrelationship. To comprehend that complexity, current thought leaders in the discourse of science, technology and the arts suggest a new dimension to their interaction: that of artist as researcher and lead provocateur in integrating space science as part of the normal day-to-day cultural discourse. For scientists and engineers on the other hand, the suggestion is to expand their mental agility by employing an artful approach to their work as a problem solving or design enhancing strategy.

Scientists and artists work in concert with each other, and overlap where their polymathic abilities allow. Few scientists are able to draw a perfect circle freehand or master the technique of chiaroscuro and, conversely, few artists are able to calculate when as asteroid might hit Earth, or determine the properties of black holes, but neither are they required to. The two disciplines are multifaceted, they maintain their pure and applied parameters yet are able to utilize a middle ground which incubates cross-over concepts, processes, and actualizations. In the best case scenario, the overlap incubates innovation in both disciplines, separately and collectively.

The objective of increased Art/Sci integration is not to homogenize the two disciplines in such a way as would be detrimental to one or the other. Scientific research is based on the laws of nature, and its creativity stems from those laws; whereas artistic research is relatively lawless, its restrictions stemming from only the limits of the imagination and of the physical properties of the materials involved. As scientist/artist Francois-Joseph La Pointe points out in *The Role of Experimentation in Art and Science*, one should not confuse art with artistic approach and similarly, one should separate science from the concept of scientific research (Lapointe, 1942).

As individuals, one can adopt an artistic approach to one's science, and a scientific approach to one's art. As team members, the cross pollination stimulates a creative approach to the mission at hand. That is the beauty of it all, that the sum is greater than the parts, which allows societies to benefit faster and more sustainably from the application of that creativity.

5.1 Artist as Researcher

The plasticity of the creative impulse allows artists to participate in space science from several different vantage points: that as commentator, as communicator, as researcher, or that as collaborative participant. The value of research inquiries conducted by artists lie in their ability to offer alternatives in setting research agendas, inventing new methods, interpreting results and communicating findings, thus transforming the frontiers of science (Wilson, 2002). Where art and science disciplines meet is in the arena of research as a method of inquiry. To participate more effectively in research within the discipline of space science, artists are going to have to lean in, to acquaint themselves with the laws of nature that surround the idea or object about which they seek to collaborate.

5.2 Art characteristics adaptable to scientific research

Stephen Wilson, American artist and author, was among those who realized that as the arbiters of cultural change, artists must engage with technological and scientific research beyond just using the new content. To begin the process of inquiry, an artist must first analyze the myths surrounding science and come to the realization that basic scientific principles are not incomprehensible and that technological imagination and scientific inquiry are within the capacity and purview of an artist. Characteristics inherent in an artist that can be brought to the table in a scientific inquiry are (Wilson, 2002):

- A tradition of iconoclasm means that artists are likely to take up lines of inquiry devalued by others.
- The valuing of social commentary means that artists are likely to integrate widely ranging cultural issues into their research.
- Artists are more likely than commercial enterprises to incorporate criteria such as celebration and wonder.
- Interest in communications means that artists could bring the scientific and technological possibilities to a wider public.
- The valuing of creativity and innovation means that new perspectives might be applied to inquiries.

Joel Slayton explains in the foreword of Wilson's book that the Arts bring with it the essence of the Humanities and the responsibility to oversee science for the benefit of culture and society. Therefore, with the new perspectives artists bring to the table, artists could expand the science agendas and extend the possibilities of what space science could accomplish for the global commons. Slayton believes that utilizing various branches of knowledge to create a vibrant transdisciplinary culture can be seen as a fertile terrain in which art informs research and research informs art (Wilson, 2002).

5.3 Transdisciplinary Collaboration

The accomplishments of the 20$^{\text{th}}$ century space age were wrought from a combination of technological and engineering trial and error, professional verve, and a quest for excellence (space race political dominance and false pride aside). Space exploration in the 21st century has been built on those accomplishments, but also faces a newer, wider, and more encompassing conceptual frontier that requires further integration and overlap in the space adjacent fields.

The incrementally more complex nature of the space arena in a space-savvy global information age requires a transdisciplinary approach woven from the fields of engineering, physics, biology, materials science, astronomy, cognitive science, medicine, architecture, social science, information science and art, and from any field that can offer creative input, perspective, analysis, and problem solving approaches relating to traveling, living, working and practicing art in space. Space science's influence on society, for example, the ability of satellite data to address 13 of the 17 current United Nations Sustainable Development Goals (SDGs), is far too great a responsibility to be left in the realm of one discipline alone.

It has been said that science and art are mutually enabling. Artist Arthur Woods sees that mutually enabling environment as essential to meet the growing needs of humanity. In his statement in the *Next Millennium: A Space Age or Stone Age*, he notes:

> *"The future of space activities, the future of humanity and perhaps even the future all life on earth is in need of skilled communicators possessing the knowledge and understanding of the scientists combined with the intuition and sensitivity of the artist."*
> - Arthur Woods (Wilson, 2002)

This blending of scientific knowledge and intuitive sensitivity can only be maximised by artists and scientists engaging in transdisciplinary collaborations, the combining of several branches of knowledge. Globally there are many sectors of industry, government, academia and civil society that are focused on exploring how to best plan, train, implement and profit from transdisciplinary collaboration. To accomplish such a wide range of agendas requires that new research and development modalities and approaches guided by the analysis of sustainable best practices are necessary (Mejía et al., 2017).

To that end, Roger Malina has taken up the task of collaborating with a team of individuals to consolidate methodologies and search for best practices. As noted in their 2017 working paper *Towards an Inventory of Best Practices for Transdisciplinary Collaboration*, Malina, Mejía and Roldán are of the opinion that the era of isolated expertise is over. Rather, they encourage integrating various knowledge systems by working in tandem, utilizing the benefits of a multiplicity of perspectives, which are motivated by the promise of collective potential (Mejía et al., 2017).

That being said, the idea of collaborations gone wrong or not living up to potential bears scrutiny. Visual artist Patricia Olynyk believes that an example of a bad collaboration for an artist would be that they are required only to illustrate a scientific concept. Similarly, for the scientist, a bad collaboration would be an artist who misrepresents the ideas and does nothing to advance the inquiry, does not incite reasoned debate, or confuses the issues (Beete, 2014). When artists and scientists collaborate well, and get the results they expect or even surpass them, both groups benefit and set precedent. Precedent, as proof of concept, has far reaching effects as it further influences funding models, user applications and mission design.

The general public are a massive funding base for space research and are presumably the beneficiaries of it, but they are not in the labs, in the clean rooms, in the studios or in the edit suites. They are informed of new art or new science or new applications via the media. In this information age what we see and what we hear about space and space technology is increasingly conveyed using media arts platforms. The creative arts ignite the imagination of the multitudes, which in turn creates a public will to support space programs and a desire to use the subsequent technological applications. Notable collaborations between creative artists and space scientists are demonstrated in the following examples how the media arts, commercial entities, the private sector and space agencies strategize their Art/Sci collaborations.

5.3.1 The Media Arts

Space science has developed its revolutionary thinking and disruptive behavior alongside the progression of technology, and so has the media arts. In the broader context of the media arts (traditional, digital, and film), the benefits of technological applications from space research of smaller, lighter and higher resolution cameras, of better audio and lighting equipment, has allowed production houses to blossom and contributed to the rise of many more media platforms upon which to broadcast. Traditional, digital, and film media too, took advantage of technological advances to depart from its traditionally structured and expensive commercially controlled content and broadcast methodology.

This conjunction of smart disruptive technology, a plethora of platforms, a growing number of creative producers, writers and editors servicing an educated, interested public have enabled scientists to expand their reach beyond the scope of their universities or labs, and even of traditional media platforms. That expansion has in turn created a public demand for information and programming; and subsequently, the space scientists are filling that demand.

Diverse platforms serve as new outlets for scientists, engineers and the space community. They must become conversant with working amid a vast media network to translate scientific concepts for the general public via the news, special features, documentaries, films, articles and online media. The popularity of their programming also effects their professional reputations and that of the institutions they represent. The institutions further capitalize on said popularity in their fund raising strategies. It is a cyclical relationship between the media arts, science and education.

The wondrous nature of space and astronomy have attracted many great scientific minds over the 20^{th} and 21^{th} centuries. And of those, there have been many outstanding people who developed a personal style of engaging with the public through excellent training provided by production companies. Names like Wernher von Braun, Carl Sagan, Stephen Hawking, Bill Nye, Carolyn Porco, and Neil de Grasse Tyson are a few who have popularized science concepts by the force of their on-screen personalities. They have developed a camera friendly persona of insightful intelligence and engaging camaraderie. In turn, scientists have been called upon to oversee the accuracy of film scripts, background settings, and documentary scripts relating to science.

All forms of media content can shape public perception, however, film and television in particular have the critical mass to quickly sway the public narrative about the value of space to society. The Art/Sci relationship has been particularly exploited by those in the film industry, who use space technology to expand their cinematographic potential and provide access to space itself.

Behind the scenes, script writers render the written word and visual artists set the scene for an episode and its story line. The scriptwriters of *Star Trek*, which first began airing 53 years ago, allied themselves with engineers and astrophysicists to render their scripts as authentic as possible, so that their fiction would seem plausible. This degree of authenticity in the look and feel of the environment has enabled science fiction scripts to convincingly portray space exploration and colonization as a viable possibility. Three such collaborations are discussed in the following sections.

5.3.1.1 Gregory Benford

As a consultant for *Star Trek: The Next Generation* physicist Dr. Gregory Benford was an auspicious choice. A prolific writer, Benford advised NASA and the White House Council on Space Policy, authored over twenty novels, and earned the 1990 United Nations medal in literature. That creative relationship lent credibility to the new TV series at a crucial time in its development in 1987, and helped sustain its audience ratings for its seven-year run (Benford, 2019).

Benford's authentic perspective did its part in keeping *Star Trek: The Next Generation* on air, and able to create story lines at the leading edge of geo-political, and socio-cultural norms. All of this also served to keep the infinite possibilities of exploration and colonization fresh in the minds of successive generations for over five decades.

5.3.1.2 Stephen Hawking

Actors are often drawn into the arena of space as presenters. Conversely, space scientists are also drawn into various disciplines of the media arts. One of the best respected, and perhaps the least expected to be on screen, though, was physicist, author, presenter, and actor, Professor Stephen Hawking. Hawking was an iconic theoretical physicist and cosmologist, but he was also a showman and a bestselling author. An ardent science fiction fan, Hawking entertained a second career in television and film as a host, an actor, a narrator, a voice-over artist, a guest star, a subject, and a writer.

(a) (b)

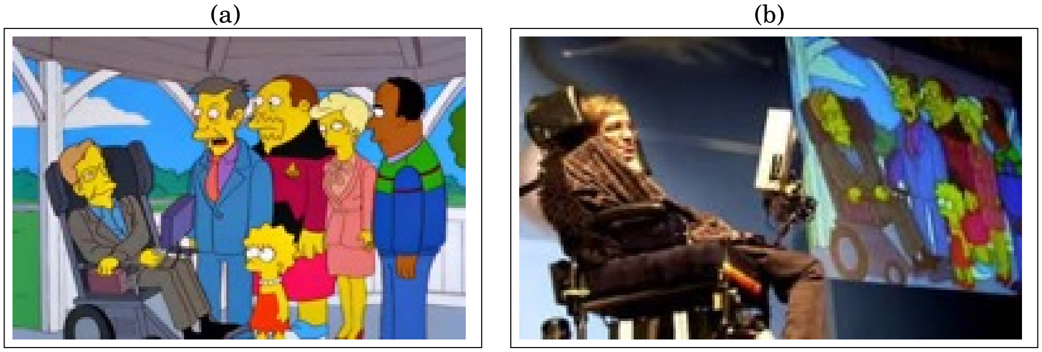


Figure 5.1: (a) A still of Stephen Hawking on *The Simpsons* in 1999 (Grady, 2018); (b) Stephen Hawking made several appearances on TV show *The Simpsons*. Here he shows a clip from the show during a presentation at a conference in India in 2001 (Fleishman, 2018).

Spanning the years 1992-2018, TV Guide lists Hawking's credits as a Host for *Grand*

Design, *Genius*, *Brave New World*, *Stem Cell Universe*, *Into the Universe*, and *Stephen Hawking's Universe*. His acting credits include TV shows *The Big Bang Theory* and *Star Trek: The Next Generation*, and in the movies The *11th Hour* and *A Brief History of Time*, for which he also has a writing credit. Additionally, Hawking narrated a *Danger Decoded* episode, *Sci Fi Masters*, and *Masters of Science Fiction*. He has voice credits for TV shows *The Big Bang Theory*, *Futurama* and *The Simpsons*, and his voice is also featured in two pink Floyd albums: *The Division Ball*, in 1994 and in *Endless River*, 2004 (TVGuide, 2018). Hawking's life itself and his science have also served as content for documentaries and films.

5.3.1.3 Carolyn Porco

An expert consultant for NASA, Carolyn Porco is a planetary scientist, whose career includes working with the Voyager missions in the 1980's, leading the imaging team for the Cassini Huygens mission, directing the Cassini Imaging Central Laboratory for Operations (CICLOPS) and directing the Imaging teams of New Horizons Mission to Pluto and Kuiper belt. In 1999 she was named one of the top 18 scientific leaders of the 21st century by the London Sunday Times, and in 2012 Time Magazine included her on the list of "25 Most Influential People on Space" (Space Science Institute, 2016).

Figure 5.2: A photomanipulation of Carolyn Porco in a *Star Trek* uniform by Richard Soppett, from an original photograph by Phil Mumford (Soppett, 2011)

An astronomy consultant over a spread of media, Porco's television and film credits include the 2009 *Star Trek* movie, the BBC's *Stargazing Live*, *The Century*, *The Planets*, *A Traveller's*

Guide to the Planets, *Horizon*, and a *Nova* Cassini special. Her TV episode credits listed on the Internet Movie Database (IMDb) are *Could a Saturn Moon Harbor Life?*, 2006, and *Carolyn Porco Flies Us to Saturn*, 2006 (IMDb, 2019*a*).

In the 2003 film *Cosmic Journey: Voyager Interstellar Mission and Message*, Porco appeared onscreen and also served as the show's science advisor and animation director. In the 1997 film *Contact*, based on Carl Sagan's book, the heroine was formulated on Carolyn Porco's persona and she served as advisor to the main character (Space Science Institute, 2016).

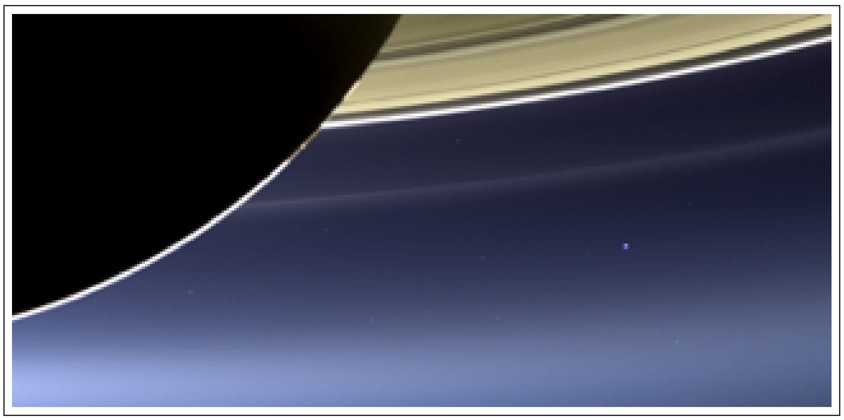


Figure 5.3: *The Day the Earth Smiled* is Cassini's image of Saturn and Earth. On 19 July 2013, NASA's Cassini spacecraft slipped into Saturn's shadow during an eclipse of the sun and turned to image the planet, seven of its moons, its inner rings - and, in the background, for the first time, Earth's inhabitants knew in advance their picture was being taken from a billion miles away (NASA/JPL-Caltech, 2013).

Her polymathic abilities extend to having an eye for film and photography. In addition to becoming camera friendly herself, she honed her skills behind the scenes as President and CEO of Diamond Sky Productions, which focuses its mix of scientific planetary imagery and computer graphics to bring science to the public. Porco finessed her satellite cameras including the portrait of the solar system taken by Voyager 1 (Voyager1, 1990) and Cassini's image of Saturn and Earth (shown in Fig 5.3) to create some of the most iconic images of space thus far.

5.3.2 Commercial Sector

Within the space economy, the commercial sector is growing with every new or improved piece of space technology. This growth is concerning to sociologists who are calling for a "socially robust" science to be embedded in society; and by extension, into the commercial application of science.

5.3.2.1 PLANET — using art to expand our understanding of life on Earth

Silicon Valley's smallsat industry disruptor, Planet, utilizes the concept of visual-art-meets-space-science in an original way. The nanosats in their Dove flock constellation are decorated with artwork created by artists, employees and the public. The idea sprang from a chance encounter between an artist and an entrepreneur attending a "Curiosity Camp" hosted by a venture capital firm linked to Google's parent company Alphabet in 2013 (Wong, 2017). Forest Stearns, the artist, now manages Planet's artist-in-residence program. Robbie Schingler, the entrepreneur, former NASA scientist and Planet co-founder, sets the tone of the art in line with Planet's mantra:

> *"We hold a bedrock belief in the power of the arts to enrich, challenge, and expand our understanding of life on Earth. We bring together art and science to build a culture of creative entrepreneurship and innovation at Planet"*
> - Robbie Schingler (Planet, 2019)

Some five-hundred painted satellites later (half of which are in orbit, the other half waiting to go into orbit), Planet boasts on its website to have created the largest art exhibition in Earth's orbit, both in the ISS orbit and sun synchronous orbit. Stearns has collected hundreds of illustrations and famous quotes for inclusion on the satellites. Planet's work spaces, receivers, dishes and rockets also get the make-over.

Stearns created a mural on two domes that celebrate radio waveforms and the path of orbiting satellites. The undulating lines on the first dome illustrate wave forms and the orbit of Doves deployed from the ISS to space. The stylistic lines on the second dome interpret Dove orbits and oscilloscope wave forms in sun synchronous orbits.

Planet bridges art, science and social responsibility by offering their global remote sensing data to the United Nations' Sustainable Development Goals. Art work has a multi layered function at Planet. It serves to galvanize the employees, and is at the core of Planet's public

(a) (b)

Figure 5.4: (a) A Dove satellite, Build 31, painted by Forest Stearns, 2013 (Planet, 2019); (b) Planet uses artmaking as a way of engaging with employees, family members, communities and the next generation (Planet, 2019).

relations platform as the focal point of human rights and sustainable development missions. Art work provides Planet the kind of visceral bridging mechanism between the arts and the sciences that they had been searching to establish. It is how to make their artful science inspire a good artist, who in turn, inspires good science which in turn, inspires global reciprocity.

Figure 5.5: *Waveforms and Orbits* spray-painted on two 7-meter Planet radomes in Awarua, New Zealand, by Forest Stearns (Planet, 2019).

(a) (b)

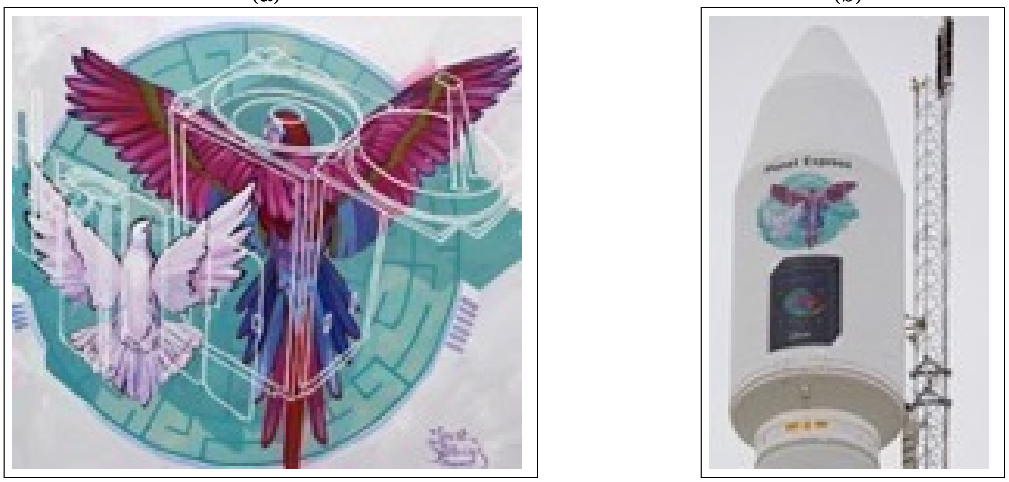


Figure 5.6: (a) Acrylic painting on canvas, transferred to Orbital ATK Minotaur-C rocket, by Forest Stearns (Planet, 2019); (b) Stearns' art on the Minotaur-C at lift-off (Clark, 2017).

5.3.3 Non-Profit Sector

5.3.3.1 Shared Sky: The SKA's Indigenous Astronomy/Art Dialogue

Artists, astronomers and indigenous peoples all share an interest in what happens in the sky. To accommodate the vastly improved technology of astronomical devices in modern times, astronomers require more and larger telescopes to be built on tracks of land located in sparsely populated areas. Some of those desired locations are on culturally sensitive indigenous lands. Recently, the desired locations have resulted in a clash between culture and science with the proposed builds of the Square Kilometer Array (SKA) in Australia and South Africa.

As Australian and South African astronomers were in the planning stages of developing the SKA, the effects on the indigenous populations demanded accommodation. In an unprecedented public relations move to develop unity across communities and continents, SKA astronomers in each country met with indigenous artists of Australia's aboriginal Yamaji and South Africa's /Xam-speaking San to find common ground. The issues of contention were regarding the respect of indigenous culture, indigenous participation in the project, and of sustainable stewardship of land (Mann, 2016). In resolving the issues, the artists exchanged indigenous knowledge about the cosmos and humanity's place in it and astronomers shared their discoveries of the universe.

(a) (b)

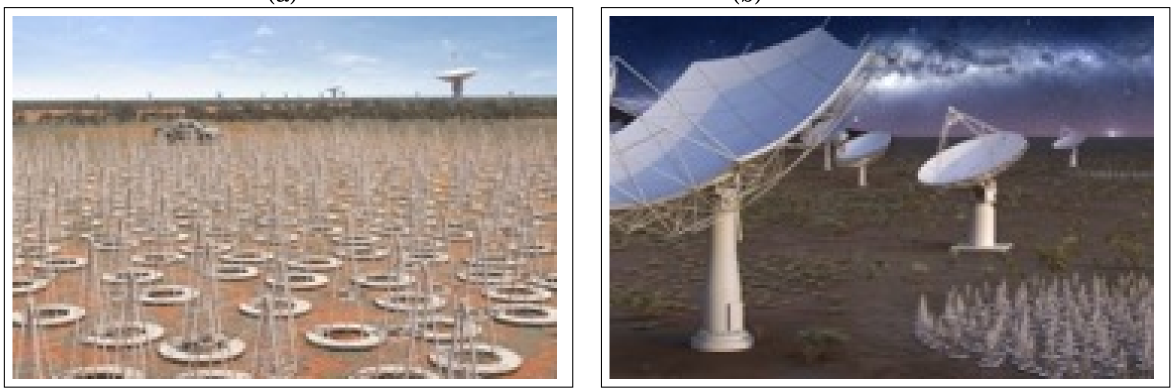


Figure 5.7: (a) Artists depiction of the SKA low frequency aperture arrays and ASKAP dishes in Australia (Square Kilometer Array (SKA), 2018); (b) Artists rendition of the SKA1 array and MeerKAT dishes in Africa (Square Kilometer Array (SKA), 2018).

The end result of the verbal and pictorial exchanges and the arts workshops is that both groups agreed that astronomy and indigenous practice are not inherently at odds, that both groups had a keen interest in astronomical discovery, and the benefits of science must be shared for the benefit of humanity. The results of this encounter were celebrated in the *Shared Skies* art exhibition in 2014, reminding all viewers that space has inspired all people, everywhere since time immemorial.

The Yamaji pieces for *Shared Sky* were done in a traditional Aboriginal dot painting style, and the South African needlework tapestries incorporated visual motifs that stretch back to antiquity as well as reflecting the SKA dishes as sculptures in the landscape (Mann, 2016). *Shared Sky* opened at the John Curtin Gallery in Perth, Australia in September 2014, traveled to the Iziko National Gallery in Cape Town, South Africa in 2015, then toured European venues until 2018.

The benefits of this collaboration are manifold: it served the artists by providing the ways and means to work individually and collaboratively, by providing an introduction to an indigenous group from another country, and inspirational new content from the first-hand scientific insights of astronomers. The collaborative process provided astronomers a rare opportunity to conduct meaningful exchanges with indigenous artists, and the potential to expand their world view. Exhibitions of art are unparalleled in their ability to educate the public, and provide scientists with a cultural platform from which to coalesce support from a variety of individuals and institutions.

> *"This vision embodies the spirit of the international science and engineering collaboration that is the SKA project itself, bringing together many nations around two sites in Australia and South Africa to study the same sky reflecting the richness of the artist's ancestor's understanding of the world developed across countless generations observing the movements of the night sky."*
> - SKA (Square Kilometer Array (SKA), 2018)

(a) (b)

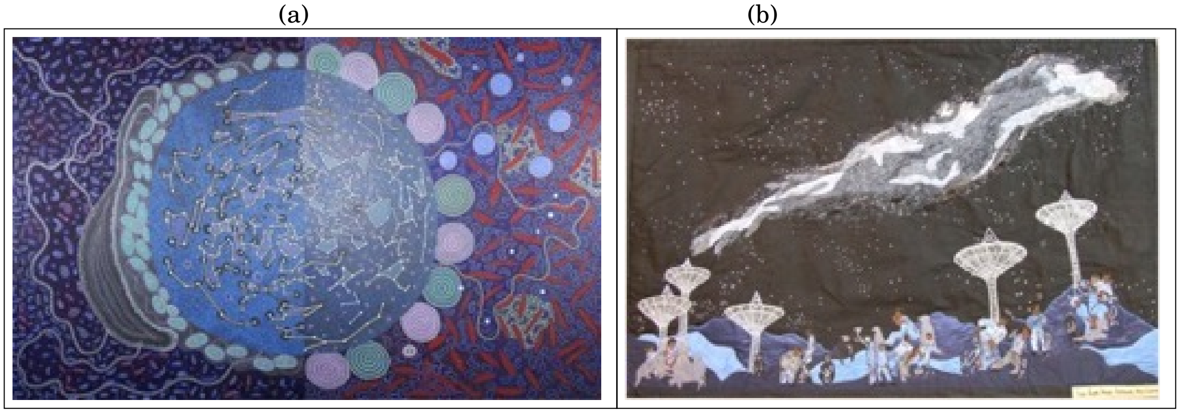


Figure 5.8: (a) For the work *Ilgali Inyayimanha (Shared Sky)*, the artists articulated the theme, which reads in part: "It doesn't matter where we live on Earth, we are all sharing the same sky. Although we may see different things belonging to the sky, we are looking up at the same stars and constellations." (Square Kilometer Array (SKA), 2018); (b) Indigenous artists in South Africa created this tapestry to recognize their collaboration with astronomers as part of *Shared Sky*. It's an imaginative representation of the meeting between the ancient and the contemporary (Square Kilometer Array (SKA), 2018).

5.3.3.2 Karel Nel and COSMOS

A particularly fruitful and long-running academic collaboration between artist-in-residence Karel Nel and head of COSMOS, astronomer Nick Scoville spans fifteen years and shows no signs of ending. COSMOS, the Cosmic Evolution Survey, has undertaken to map a two degree field of the universe utilizing a team of over one hundred astrophysicists worldwide. Commencing in 2004, it is still ongoing. Their resident artist is South Africa's Karel Nel, who has been inspired and informed by the ideas, insights, images and raw data issuing from radio, x-ray, infrared and optical telescopes used by the COSMOS scientists in their research.

(a) (b)

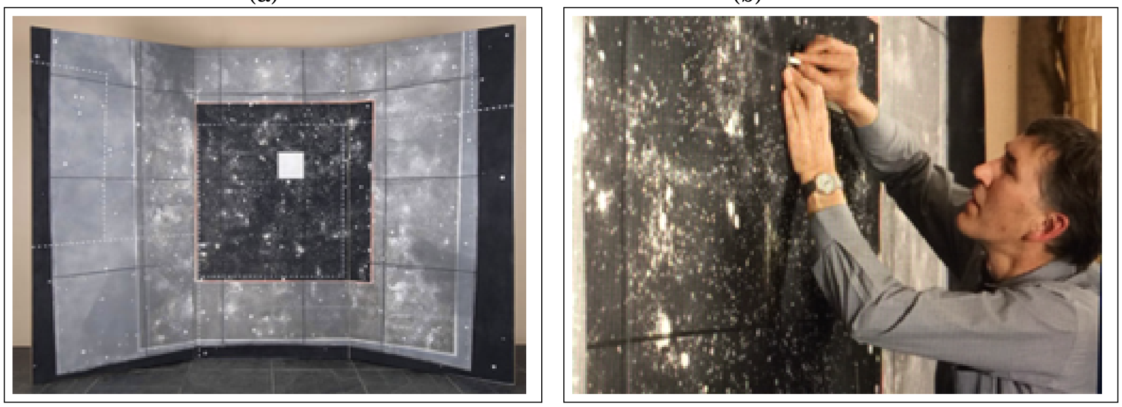


Figure 5.9: (a) *The Collapse of Time*, by Karel Nel, 2008, 3-part screen (Nel, 2008a); (b) *The Collapse of Time*, detail. Karel Nel plotted precise star placement in his work (Nel, 2008b).

Using carboniferous rock and salt, Nel's task encompasses translating in two dimensions the human capacity to map and comprehend the origin of the universe and the meaning of human life in the infinite vastness of space.

"I am particularly fascinated by the fragile images of light that left their source millions of years ago. I make these momentarily tangible by using materials commensurate with their subject: 540 million year old black carboniferous dust and radiant white salt, two deeply primordial substances. The shimmering refracting surfaces of the works evoke the evanescent phenomenon of photons traveling through deep space, here materialized into dense matter."

- Karel Nel (Nel, 2008b)

From the perspective of Nick Scoville, Moseley Professor of Astronomy at Caltech and Leader of COSMOS, the value of a resident artist is to bring out the commonality between the aspirations of both artistic and scientific endeavors, a desire in each case for unification and distillation of diverse phenomena, together with an appreciation of beauty and elegance - physical as well as philosophical (Nel, 2008b).

"Often in our profession, one becomes fixated on the details of narrow corridors, losing sight of the interconnectedness and poetry of the whole. Karel's images distill these connections metaphorically, much like the physicist uses equations to unify phenomena in diverse environments and over vast ranges of scale."

- Nick Scoville (Nel, 2008b)

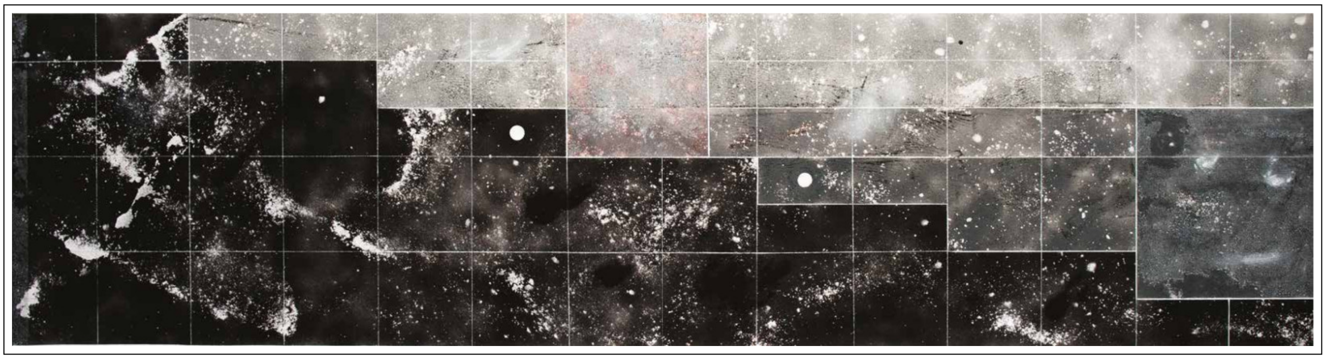


Figure 5.10: *Stepped Stellar Messages*, Karel Nel, 2015. Pastel, metallic dust, specularite and dry pigment on bonded fibre fabric, 850 x 2950 mm. Elizabeth Burroughs describes *Stepped Stellar Messages* as "the layering of the images - messages from far distant galaxies are elusive clues which need to be pieced together. Shimmering subtly with a scatter of specularite, the location and orientation of the image is difficult to read, as an inter-galactic void fills the lower portion while the opaque silvery messages lie stacked above. Without the defining linear grids, the information and the possibility of comprehension collapse" (Burroughs, 2015).

5.3.3.3 LightSail 2

LightSail 2 created a revolution in space as the first totally crowdfunded solar sail project. It was supported by donations, corporate support and ardent members of the Planetary Society, a non-profit space advocacy group. LightSail 2 was launched on 25 June 2019 aboard the SpaceX Big Falcon Rocket, and deployed by Proxi-1, a Georgia Tech student-built small satellite. LightSail 2 phoned home on 2 July 2019 and began its main task of raising its orbital energy by harnessing sunlight, and relaying images. LightSail 2 was declared a success on 31 July 2019, when it raised its orbit solely on the power of sunlight.

LightSail is a disruptive technology with something to prove. It's the first spacecraft in Earth orbit propelled by sunlight with the capability to raise its orbit (The Planetary Society, 2019). It is a game changer in terms of lowering the cost of space exploration and setting the stage for researching many more satellite designs and long-term missions unencumbered by the need to carry fuel. The Planetary Society's ability to raise the 7 million US dollars required for Light Sail project took advantage of the intelligence of a savvy citizen population and the force of the public will.

(a) (b)

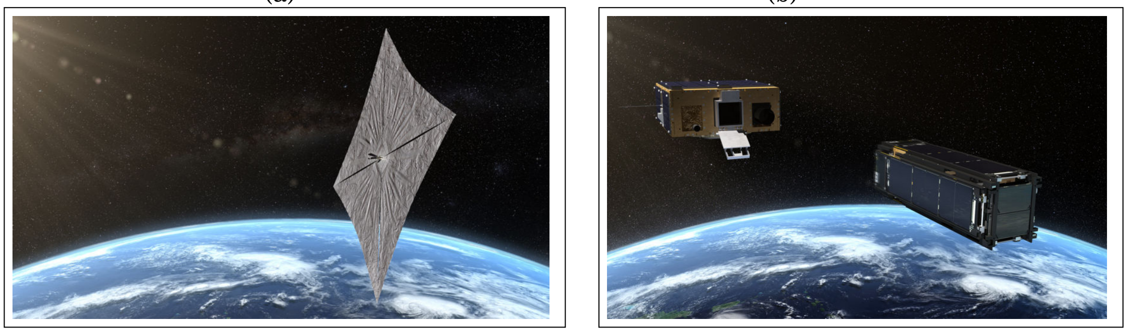


Figure 5.11: (a) Josh Spradling's 2017 concept art of LightSail 2 above Earth with the solar sail fully deployed; (b) Josh Spradling's 2017 concept art of Proxi-1 deploying LightSail 2 in orbit (Spradling, Josh, 2018).

These examples are only the beginning in the development of solar sails satellites for sustainable science, such as its potential for targeting space debris, and of what can be accomplished by the inclusion of the public in the space community.

5.3.3.4 #DearMoon

There is hope on the horizon for direct artistic participation in lunar missions. On 18 September 2018, Japanese art collector and entrepreneur Yusaku Maezawa, and Space X founder Elon Musk announced a mission designed to place artists in orbit around the moon (Dickson, 2018). Maezawa is a philanthropist who wants to drive humanity forward by offering the inspiration from the art produced on the trip and long afterwards. Perhaps as early as 2023, artists will take their place in the forefront of the space community by creating space-based art on location, in cislunar space.

Maezawa integrates the value of art to space science, and the value of space science to humanity, and envisions this trip as a universal art project that will contribute to world peace (Maezawa, 2018). Although they may be currently referred to as "tourists", these artists should be more aptly named "mission specialists", as they are there for a purpose, in a job that only they can accomplish.

5.3.4 Space Agencies

The major space agencies have also taken advantage of the appeal of space to the public and the use of the media to transmit their content. They have dedicated TV channels which play their live action, and educational documentaries to keep the public informed. NASA and ESA are examples of space agencies that have successfully incorporated art within their public relations mandate to educate and engage the public.

5.3.4.1 NASA Art Program

"Ars Longa, Vita brevis" (Art lasts, life is fleeting)
- Hippocrates (Bartlett, 1939)

Hippocrates famously postulated the belief that life is brief, but art lives long. His sentiment could also have been the underlying basis of NASA's Art Program, established in 1962, four years after NASA was founded. Five decades later, the Art Program' collection was celebrated in a coffee table book entitled *NASA/Art, 50 Years of Exploration*. The legacy of the art program and the potential in its future were expressed in the book's foreword by one of the few people whose experience as both an astronaut and an artist afforded him such an insight, Gemini 10 and Apollo 11 veteran Michael Collins:

> *The eye of the artist fills the great gaps left by the astronaut and his camera. NASA artists have done a magnificent job of expressing the panorama of a launch... the excitement and violence of it, the smell of kerosene and the fear in the air. I am looking forward to the day when the artists will be able to look out the astronaut's window and share the breath taking view. Tom Paine, former NASA administrator, said that we must leave for future generations a truthful record at all levels of perception. For that idea to be fully realized, artists must join the astronaut in space and I hope it happens soon."*
> - Michael Collins (Dean and Ulrich, 2008)

Modern space artists in America owe a debt of gratitude to Bruce Stevenson (1898-1963), whose portrait of Alan Shepard, installed in NASA headquarters in 1961, caught the attention of NASA administrator James Webb. Webb's inspired vision to capture the journey of space exploration through art resulted in one of the finest collections of space art in the world. With over 3,000 pieces, the NASA Collection is a national treasure housed at the Air & Space Smithsonian Museum in Washington DC (Dean and Ulrich, 2008). To run the project, Webb chose visual artist and NASA Public Affairs officer James Dean, who collaborated with Dr.

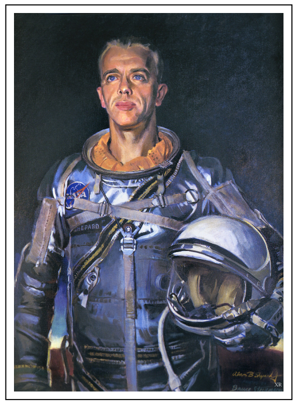


Figure 5.12: *Commander Alan Bartlett Shepard, Jr*, by Bruce Stevenson, 1961 (Stevenson, 1961). In May 1961, 23 days after Yuri Gagarin became the first human to orbit Earth, Shepard made a 15-minute suborbital flight that reached an altitude of 115 miles and in 1971 he walked on the Moon.

Lester Cooke, curator of paintings at the National Gallery of Art, in a first-of-its-kind art initiative. They selected and invited artists to NASA facilities to paint whatever captured their attention (Smithsonian, 2019).

When a major space event takes place, hundreds of video and still cameras record every split second of the activity. Artists duplicating that effort would add little to the factual record, but their purview would include recording the emotional impact, and interpreting the multi-layered significance of the events. The expectations were high, each piece had to stand on its own artistic merit, and the collection itself had to make a significant contribution to the history of American art.

> *I hope that the past held captive in the paintings resulting from the effort would prove to future generations that we have not only the scientists and engineers capable of shaping the destiny of our age, but also artists worthy to keep them company."*
> - Lester Cooke (Dean and Ulrich, 2008)

Although cameras had documented the technical details of many space events from every angle possible, for Webb, Dean, and Cooke the photographs were impersonal and lacked the emotional resonance of the achievement. They were betting that artists could express the full impact of events that would irrevocably impact the history of the world, and very likely the destiny of the human race. It was a mission the artists understood, accepted, and accomplished (Dean and Ulrich, 2008).

The first 8 artists covering the last Mercury flight in 1963 were let loose at the Kennedy Space Center and a new era of Art/Science collaboration began. Paintings, drawings and sketches were made quickly on site, followed by months of in studio work. The art produced from one single Gemini event made up most of the pieces in an exhibition held two years later at the National Gallery of Art in Washington D.C., entitled *Eyewitness to Space*.

The exhibition drew nearly 67,000 visitors, second only to the visit of da Vinci's *Mona Lisa* (Smithsonian, 2019). NASA gained extraordinary public good will, and cemented Webb's dream into a historical archive like no other. More public exhibitions followed, and NASA took advantage of the media's growing interest in covering the space program. Eventually hundreds of cameras, national and international, were focused on launch and recovery events in every site.

(a) (b)

Figure 5.13: (a)*Sunrise Suit Up*, Martin Hoffman, 1998. Hoffman captures astronaut suit-up through the television screens in the media area at the Kennedy Space Center. The countdown clock is in the forefront and the launch pad can be seen in the distance beyond Banana River. It is one moment of calm before the frenzy of launch activity (Hoffman, 1988); (b) *Strange Encounter for the first time*, Clayton Pond, 1981. Pond juxtaposes science reality with science fiction as he presents the NASA shuttle craft "Enterprise" encountering the "Starship Enterprise" from the *Star Trek* TV and film series in outer space (Pond, 1980).

NASA began initiating pre-emptive public relations initiatives to justify to the tax-paying public the importance of the Shuttle Program and its benefits to humankind. Artists were commissioned to document the Shuttle Craft project before the Shuttle craft actually flew. Most famously, Norman Rockwell's painting depicting *Man's First Step on the Moon* predated Armstrong's actual first footstep by three years.

In what must be one of the most iconic moments in the category of life imitating art in television history, the *Star Trek* TV series aired in September of 1966, and popularized space exploration. A decade later, the first test Space Shuttle, designated OV-101, and slated to be named the Constitution, was renamed "Enterprise" partly in response to a massive write-in campaign spearheaded by Star Trek fans. White House advisers cited "hundreds of thousands of letters" from fans as a reason for giving the shuttle the name. Although President Ford did not publicly mention the campaign, he himself had served on a Navy ship named Enterprise, and, in the end, he directed NASA officials to change the name (LiveScience, 2012).

Whatever the combination of reasons, NASA exploited the situation. In 1976, when Enterprise was rolled out of its plant in Palmdale, California, the VIP guests included *Star Trek* creator Gene Roddenberry and most of the cast of the original *Star Trek* series, and the show's theme music was played. The film *Star Trek: The Motion Picture*, released in 1979, reciprocates, and contains a scene where one captain shows another paintings of former spaceships that were named "Enterprise," and NASA's space shuttle is included (Evans, 2010).

Figure 5.14: *Star Trek* creator Gene Roddenberry and the cast of *Star Trek* (the original series) with NASA administrators, attending the roll out ceremony of the space shuttle Enterprise (Uri, 2019).

Artists enjoyed the subject of space, and created artworks in any style or genre that caught their fancy. Some, like NASA collection contributor Dan Namingha, combined traditional symbolism with space-based iconography. Namingha presented a combination of his Hopi culture with space technology, as seen in his painting *Emergence* shown in Fig. 5.15.

Figure 5.15: *Emergence*, Dan Namingha, 1986. The astronaut in free flight is protected by the twin warrior guards floating on either side, whose duty it is to protect human beings, land and water. The sun spirit to the right center represents light, warmth, and life. The flute player symbolizes the strength of plant life and nature, alluding to the beauty of Earth floating in the background (Uri, 2019).

In addition to the publicity surrounding the well-known artists who contributed, the educational outreach among the general public was far reaching, and greatly contributed to the sense of national pride and the national will to support a fledgling NASA. The art works also tapped into the nostalgia of a generations born into a culture of science fiction, and NASA used those influences to galvanize spaceflight into popular American mythology.

Although the art program was drastically scaled back in the ensuing years, since the end of the Apollo missions, the working relationships between artists and scientists continued to thrive. In collaboration with NASA's Jet Propulsion Laboratory, artists created visual imagery to inform the public about current missions that were not possible to comprehend without an artistic visual reference. Two such examples were the Cassini Mission probe's dramatic descent into Saturn, shown in Fig. 5.16(a), and the discovery of the Trappist-1 system of exoplanets, depicted in Fig. 5.16(b) (Hotovy, 2017) .

(a) (b)

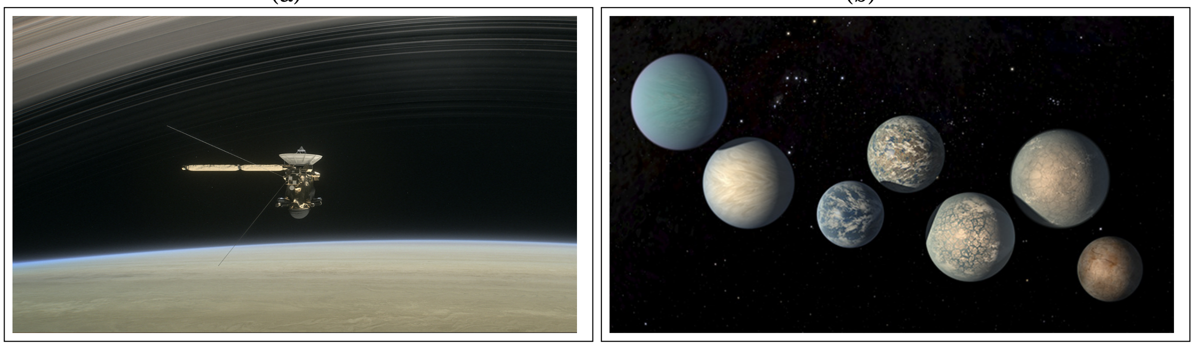


Figure 5.16: (a) In a still from the 2017 short film *Cassini's Grand Finale*, the spacecraft is shown diving between Saturn and the planet's innermost ring (NASA/JPL-Caltech, 2017); (b) This illustration, drawn from a vantage point near planet TRAPPIST-1f, shows the seven Earth-size planets of TRAPPIST-1. It is an exoplanet system about 40 light-years away, based on data current as of February 2018. The image shows the planets' relative sizes but does not represent their orbits to scale. The art highlights possibilities for how the surfaces of might look based on their newly calculated properties (NASA/JPL-Caltech, 2018).

In each of these illustrations on their scientific websites, and on so many more websites, power point presentations, printed material and videos, the visual artist, illustrator, or graphic artist's name is not directly attached to their artwork. Unfortunately, this is a common occurrence which needs to be corrected to be inclusive. Imagine a scientist publishing a paper without their name being included prominently, but rather, somewhere in the credit listing. It wouldn't happen. After all, the Theory of Relativity is known as "Einstein's" Theory of Relativity, not "A Scientist's Depiction" of the Theory of Relativity. To subsume the artist's name within the entity that funds the product may be common practice, but it is definitely not best practice in the eyes of this author.

In 2016 a scenario came to light that could not even have been imagined by artists at the onset of the NASA art programme back in 1962. NASA sent out a call for artworks (digital sketch, photograph, graphic, poem, song, short video or other creative or artistic expression that reflects what it means to be an explorer) to be included on a chip aboard the Origins, Spectral Interpretation, Resource Identification, Security, Regolith Explorer (OSIRIS-REx) spacecraft which arrived at the asteroid Bennu in 2019.

After a brief touchdown on Bennu, OSIRIS-REx will return rock samples down to the Earth when it passes back by in 2023 (NASA, 2016). The remainder of the spacecraft with its digital art gallery on board, will move into orbit around the sun where It will remain for millennia. The public has even been invited to help choose the landing site on the asteroid.

The idea is not simply just to send artwork flying around space to very likely never be seen again or to become space debris, it is to focus the public's attention of the importance of studying the science of asteroids, especially Bennu, which stands a chance of hitting Earth in 2182 (Epstein, 2016). This kind of opportunity for the public to become citizen artists/scientists may seem unprecedented, but it is actually a logical extension of the legacy of inclusion inculcated by the NASA arts program.

5.3.4.2 The European Space Agency (ESA)

The European Space Agency (ESA) comprises of 22 member states: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland and the United Kingdom. It has been progressively participating in art/space collaborations since its inception in 1975.

ESA holds the view that space missions, space ships, and space stations can host a large theatre of artistic activities that allow the public a greater experiential relationship with space. The ESA Technology Transfer Office (ETTO) has acknowledged a growing interest for ESA involvement in projects of art, particularly as it relates to technology. This sketch details three examples of such art involvement in the fields of academics and engineering.

Space Art Database

ESA has assisted with funding of a Space Art Database in collaboration with France's *Leonardo*/International Society for the Arts, Sciences and Technology (ISAST) and Switzerland's OURS Foundation, a not-for-profit cultural and astronautical association that comprehensively documents the genre of Space Art for the benefit of artists, art historians, scientists, journalists, curators, critics, academic researchers, educationalists and the global public at large. In keeping with its mandate to be available to as many people as possible, Space Art Database is international and multilingual. This site is housed at www.spacearts.info.

Artist in Residence

As ESA is building its collection of space art, it has also expanded to offer an artist in residence position to Spanish conceptual artist Jorge Mañes Rubio. Rubio was appointed in 2016 to ESA's research and development Advance Concepts Team among others from a wide range of Art/Sci disciplines. The team members serve dual purposes: to make space science more user friendly for the public and to widen the scientists' understanding of the broader implications of their work. In turn, artists can take advantage of the team's responses and reactions to their individual Art/Sci projects (Schwab, 2017).

(a) (b)

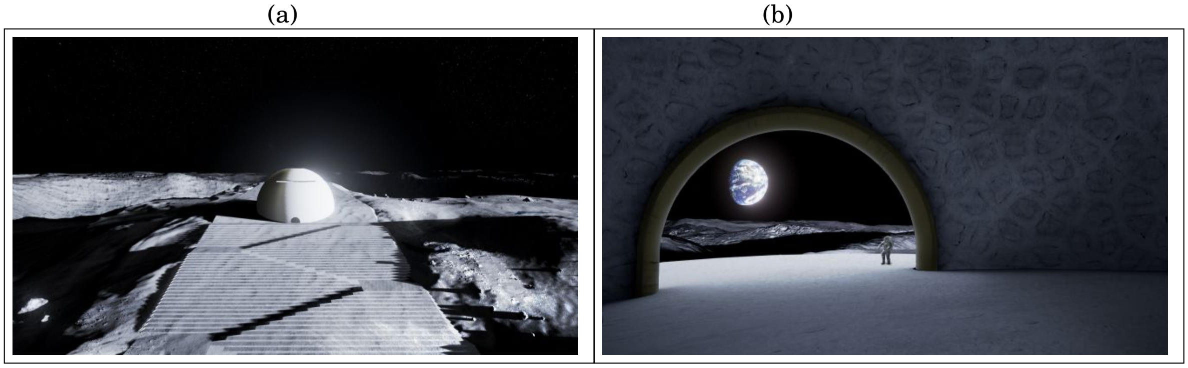


Figure 5.17: (a) *View of the Moon Temple*, Jorge Rubio, 2017, depicting the stairs and the entrance (*Visit the Moon Temple: Artist Jorge Mañes Rubio's Lunar Vision in Images*, 2017); (b) *Interior of the Moon Temple* Jorge Rubio, 2017 (*Visit the Moon Temple: Artist Jorge Mañes Rubio's Lunar Vision in Images*, 2017).

Rubio created an architectural structure that would serve as a unifying symbol of the *Moon Village*, encompassing the global fascination with the Moon with the mythology of space. It serves as a monument to art and a reminder that the Moon does not belong to any nation or adhere to any creed. His Moon Temple is inspired by French architect Etienne-Louis Boullee's 18^{th} century Utopian designs.

Rubio takes full advantage of the reduced lunar gravity to create a 165-foot dome astronomical observatory which frames a view of Earth. How it would be 3D printed in the lunar surface, and constructed atop Shackleton Crater in near perpetual sunlight was a collaborative decision from the scientists on the Advanced Concept Team. Rubio designed one opening in the dome to look Earthwards, while another at the top will peer out into deep space. As a next step, Jorge aims to create small sculptures and artifacts out of simulated lunar materials (ESA, 2017). In 2005, ESA's Senior Technology Transfer Officer, David Raitt, foresaw a dynamic role for artists in the agency's space program.

> *"The ESA Space Arts Programme will stimulate and motivate artists to translate the experiences of space into artwork and by so doing broaden human perspective, consciousness and imagination towards space as a new and significant dimension for humankind"*
>
> - David Raitt (Raitt, 2005)

Johann-Dietrich Wörner inherited the Space Arts Programme two years later when he assumed the mantle of ESA's Director General. Thus enabled, ESA's team spent several years developing the concept of the Moon Village to which Wörner invited international participation in 2015 (ESA, 2016). Space Agencies like ESA play a seminal role in providing the infrastructural umbrella from which other agencies, government departments, the commercial world, private interests and the public can operate in a focused and collaborative manner.

The future for space art initiated by global space agencies, combined with private and public sector initiatives, looks encouraging. With the USA returning to the Moon, the Lunar Gateway being built, Mars exploration on the cards, the #DearMoon project, and all major space agency players globally focusing on a variety of achievements, new commissions or subsidies might be back soon. And those historic events will be documented, translated and enshrined by artists.

With the new content and space age tools at their disposal, artists will be busy for hundreds of years to come, and future generations will be inspired by the fruits of their labor. The space art created from these international efforts will be part of the collections from which curators will choose the pieces that will become future exhibits in museums on the Moon, Mars and beyond, before the next millennium and long after.

Chapter 6

Space Art in the Global Commons and in Global Education

6.1 The Global Commons: The Earth's unowned natural resources, including oceans, atmosphere, and space

The 1967 Outer Space Treaty established all of outer space as a "global common" and promoted international cooperation in its stewardship by codifying the notion of sharing space benefits for the well-being of all humankind. The global commons of space belongs to everyone on the planet. One could extrapolate, therefore, that belonging to all of us and benefiting all of us would require collaborative engagement and consensus between nations about which activities should and should not occur in the global commons of space.

This chapter investigates some of the issues and potential solutions regarding establishing models of governance, philanthropy, conservation, ethics, terms of engagement, and quality of management with regard to space art. Additionally, the chapter addresses the development of the STEAM curriculum to ensure sustainability of art education in the global commons.

6.1.1 Space Art Governance

It has fallen onto this generation in this century to legislate art in space, to govern its quantity, to critique its quality and its global appeal. A global governing structure is necessary to unite nations in a common purpose to take advantage of and responsibility for that which has developed from and is deployed into the common heritage of space. Currently, it is within the legal agency of individual national governments to be responsible for the activities of their citizens in space, and any object put into space is also the responsibility of the state that launched it. At present the selection process for a piece of art intended for space travel is a country-specific ad-hoc affair; there is no global oversight.

Art sent into space is viewed as one individual's cultural expression. Even so, within a global commons rubric, art also comes under scrutiny of the public as it can potentially be viewed by all and impact all countries. In an era of increased space exploration, thus more opportunity to launch, or land art into space, the decision by which an artwork is selected to be placed in orbit, on celestial bodies, in space hardware or on space stations necessitates a decision to be made by global representatives of the arts and science professions. However, international best practice in terms of criteria for curation is yet to be established, but must now be established by a consortium capable of such. Amidst great excitement from artists and great dissention from astronomers, will chaos reign as more space art projects are underway with no governance in sight?

To establish appropriate governance, its oversight would need to encompass the United Nations space governance agreements, the nature of the space sciences, and the cultural aspects of space art in terms of a global society. Space art is vast and discipline specific. One should not expect that the required degree of discipline-specific knowledge to be within the purview of a governmental body, a space agency, the military or a random civil servant, scientist, engineer, or entrepreneur employed within the structures that presently manage space activities. Those people and positions also have a temporal indication.

A problem simmering since the 1960's is the potential of space agencies to be tempted to accept large incentives to launch advertisements that can be projected against the night sky or across the moon, or on flying satellites, or on the International Space Station. There are also fears of cultural dominance in the global commons by political, cultural or religious imagery. The light disruptions for astronomers and of art becoming derelict are already highly contested issues, threatening to become a tug of war between space agencies, the commercial sector, artists, scientists and the public at large.

Governmental leadership can and will change in any given country, so that space art policies agreed upon may not be honored by the new leadership of any given space agency. However, if those policies were governed by an arts consortium under the umbrella of a globally accepted organization, such as the United Nations, which lie outside of regional political influence, agreements on space art could be assured of continuance by universal good governance.

6.1.2 Philanthropy in the Age of Disruptive Technology

Developments in the disciplines of art and education are often fast-tracked by philanthropic and corporate giving. Currently the direction of world philanthropy and institutional giving indicates that space/science, tech/innovation and education/art are near the top of the list of causes. The new disruptive tech industries have revolutionized the space industry; and they have greatly impacted the philanthropic giving landscape as well. According to *Inside Philanthropy*, history is being made as the tech disruptors are dramatically changing the traditional pattern of giving, verified by the amount of current corporate donations exceeding those of individual philanthropists and traditional foundations together, and by a long shot (Paynter, 2018).

Philanthropy is legacy driven, and often tackles global issues, blurring the lines between institutional, special interest, and charitable giving. Individual and corporate funders, such as Silicon Valley tech/space billionaires favor causes that are a natural extension of their field of expertise, but which are also very close to their heart. Such funders are impatient with the generally slow progress made from traditional philanthropic models and have changed the field forever by donating large amounts of funding for arts and education and technology to ensure they will make a permanent change to the status quo and accomplish it within their lifetimes. Disruptive technology's proclivity towards creativity, its need for innovation, and its desire to create the next generation of artists and scientists is the driving force for nurturing space artists, Art/Sci research and development through STEAM education.

6.1.3 Heritage Conservation

Heritage sites and items left on celestial bodies have acquired historical and cultural value and will require legal protection against damage from impending space explorations. In advance of such potential destruction and legal ramifications, the US based not-for-profit entity *For All Moonkind* amassed a team of space lawyers to draft a convention that addresses the issue of safeguarding sites of outstanding universal value (For All Moonkind, 2019).

As of this writing, the "The One Small Step to Protect Human Heritage in Space Act (S. 1694)" was approved by the US Senate Commerce, Science, and Transportation Committee to protect lunar heritage sites, such as the Apollo 11 lander site and that iconic first human footstep on another celestial body. When passed, the bill will require anyone under U.S. jurisdiction to obtain a license from the U.S. Government to conduct lunar activities to agree to observe recommendations developed by NASA. The bill will proceed to the House of Representatives and to the Executive office before it can be signed into law. Hopefully this would become a world trend.

6.1.4 Curatorial Ethics

The global nature of space and the importance of artful representations in it and of it requires that the criteria and selection process for choosing artworks be elevated to a professional status. The purpose of a global overview would also serve to avoid decisions predicated on personal relationships or subject to the tyranny of social, cultural or political pressures (Triscott, 2012).

To this end, in 1990, artist John-Marc Philippe published a call for a Space Art Ethics Committee to be established by an international and multicultural organization that would guarantee the responsible administration of space art (Philippe, 1990). He further suggested coordinating a world-wide media program specific to space art, merging complementary projects and coordinating pre-existing and future proposals. A global commons aesthetic can also be applied to assure political and monetary transparency that may have an effect on the research and development of any project. Philippe also addressed the thorny issue of imposing a planetary aesthetic.

"..an aesthetic on a planet wide scale, which if suitably managed, could be a veritable sign of civilization, capable of sensitively expressing and revealing an overall awareness of the whole earth and of humanity"
- John-Marc Philippe (Philippe, 1990)

Space artists and curators are cultural visionaries who comprehend the extraordinary promise space holds for art, and art for space. They possess the required experience and gravitas to develop universally accepted curatorial criteria and best practice. They are aware that the potentially volatile social/economic/political/cultural/military aspects of space necessitate a competent, international collective to oversee issues arising from art's entry into space. Placing art in the global commons requires a new model of curational methodology and stewardship. Artists/Curators worldwide are professionals who share a keen interest in the stewardship of space art and in instructing future generations to do the same.

The International Astronautical Federation also recognized the need for curatorial consultants when they formed a technical advisory committee specifically to advise on the cultural utilization of space. The UN's Department of Outer Space Affairs, and the Committee on the Peaceful Use of Outer Space (COPUOS), have acknowledged the necessity of professional consultation. The three entities that follow are examples of such.

6.1.5 Enter ITACCUS & ETTAS & ISAST

In anticipation of these governance and curatorial issues surrounding art in space, curator, writer and researcher Nicola Triscott proposed an interdisciplinary curatorial model that would enable curators, artists, scientists and specialist experts to create a collaborative, enquiry-driven, inter/transdisciplinary research practice with a framework encompassing the global commons.

In 2007, Triscott and her international collaborators requested the International Astronautical Federation (IAF) to form an international committee comprising of cross disciplinary professionals within the arts and sciences who would serve as liaisons for space agencies, space bodies and cultural organizations, and thus the IAF Technical Activities Committee for the Cultural Utilisation of Space (ITACCUS) was founded in 2018 (Triscott, 2016).

The ITACCUS view-point stems from the concept that space art is vital to the ongoing societal and cultural dialogue about space. Their mandate is to develop and raise the profile and quality of artistic and cultural activities that engage with space exploration, space science and space activities. It serves as an umbrella platform whose members carry the gravitas necessary to provide aesthetic, ethical criteria for projects, and to coordinate and promote art activities in the ever growing number of space agencies, governmental departments, commercial and academic institutions around the world.

ITACCUS has since put its agenda forward by addressing the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) regarding the inclusion of artistic and cultural activities within the space agencies' fields of activity to stimulate a wider societal dialogue about space activities, and to defend the concept of space as a common heritage of humanity (Triscott, 2016). The results of ITACCUS and other initiatives by space advocates have placed Art/Science collaborations in the purview of the international space community at large (ITACCUS, 2018).

In 2011 another initiative to set the stage for creative engagement between the arts community and space agencies commenced under the auspices of a transdisciplinary conference initiated by the European Space Agency's Topical Team for Arts and Sciences (ETTAS). Led by artist, analog astronaut, and aquanaut Sarah Jane Pell, the conference brought together astronauts, artists, curators, philosophers, cultural theorists, scientists, artists from the Japan Aerospace Exploration Agency (JAXA) and NASA, along with representatives from ITACCUS to formalize cross transfer platforms.

Although this workshop was oriented towards the ESA's activities, its findings also serve as a template for any space institution which seeks to establish a platform for accommodating internal interests and stimulating public opinion. The subject areas of cooperative engagement to integrate space and art practices are categorized under the terms of engagement and quality control. The terms of collaborative engagement with individual artists/researchers can be accomplished in a variety of methodologies, whichever best accommodates research processes and the phases of the project (Pell et al., 2014):

- Solo/individual research/work
- Tandem - concerted development based on direction interactions between an artist and space agency member
- Cluster - involving mutual work of group activities

- Strategic - consulting artists and persons from the cultural sectors are embedded into the scientific discourse to specify cultural interests.

Appreciation of the arts is subjective. It cannot be measured objectively in terms of absolutes like the laws of nature, or with the certainty of mathematics. Therefore, the terms of quality management and public engagement become a complex issue when selecting an art/research project, an artwork, a residency or an exhibition, and especially one that is funded in part or in full from public coffers. ETTAS recommends following established protocols of operation, selection and reporting adapted from those used by the National Science Foundation and other previously successful residencies such as those conducted at the European Organization for Nuclear Research (CERN).

Further, a collaborative approach should be taken to establish a board of specialists consisting of artists, curators, art historians and journalists who will engage with space agency personnel to assess portfolios, ensure quality, and oversee ethical issues. Their suggestion of the roles would include:

- Cultural/Scientific coordinator across space agency facilities (administrative)
- Mentors: Space agency Scientists and Engineers
- Board of Space/Cultural advisors (curatorial)
- Artists
- Revolving jury of experts (curatorial work, quality management).

In essence, the ETTAS proposed program establishes an administrative platform tailored to national, commercial and private interests that accommodates various Art/Sci community actors to operate and enable transdisciplinary projects to flourish. The suggestion here is that these models from Philippe, Triscott, Pell, ITACCUS, and ETTAS be used as a basis for creating a revolutionary, disruptive and collaborative platform for space art to be inculcated in the global commons of space. A globally renowned peer review journal *Leonardo*, whose sphere of influence as an ISAST platform for academics, artists, scientists should be recognized globally as a platform for setting the narrative to promote the intersection of the arts, technology, the sciences, and their value to society.

6.2 From STEM to STEAM

The momentum of space science and the industries that anchor it require replenishment of human capital every generation. The Science, Technology, Engineering and Mathematics (STEM) educational curriculum, with its global approach to sustainability, provides a heretofore untapped avenue to equalize the gender gap, and become the consummate platform to drive polymathic art and science crossover education.

To advance its lengthy inter-generational projects, to engineer space applications for society and to continue space exploration, a STEM educational curriculum was put into place to meet that demand in various countries around the world. In the United States (US), a STEM-focused educational curriculum was designed to revitalize the flagging student competency in science and mathematics, but also served to ensure the continuation of a vital, motivated and innovative technology workforce. STEM has garnered traction in the US as national, state, commercial and private educational entities have promoted a STEM curriculum protocol to further revitalize and escalate educational successes.

6.2.1 The Backstory of STEM

The STEM acronym was introduced by the National Science Foundation (NSF) in 2001 by its director of Education and Human Resources, Judith Ramaley, in reference to:

> *"...an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy"*
>
> - Judith Ramaley (NCREST, 2014)

STEM addressed education in general, and served as a vehicle to encompass cultural needs of technology field to become more inclusive of gender, race and geography. In this sense, "geography" refers to not being isolated from others who are leaders in a discipline. To being able to take advantage of being geographically located in a sphere of influence, being where the action is, and being surrounded by other creatives. The United Nations Education, Scientific and Cultural Organization (UNESCO), space agencies, and educational institutions globally, took an interest in the platform.

6.2.1.1 The United Nations & UNESCO STEM

STEM curricula address the following United Nations SDGs:

- SDG #4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- SDG #5: Achieve gender equality and empower all women and girls.

STEM has become a platform from which UNESCO can counter the social/economic disparity precisely because they recognize STEM careers are driving innovation, social well-being, inclusive growth and sustainable development, and are imperative from the human rights perspective. In 2016, UNESCO agreed with the inclusion of arts and design into STEM as suggested by its member states (UNESCO, 2019).

6.2.1.2 NASA Space STEM

NASA's Office of Education uses its national platform to develop a strong Space STEM educational program by offering opportunities for students at every grade level to participate in space research, competitions, professional development, and design challenges, with a special consideration to the under-served (NASA, 2017).

Figure 6.1: NASA STEM on Station poster (NASA, 2017).

Space STEM casts a wide net by partnering with other national departments, state agencies, and private and commercial institutes to leverage its assets such as the ISS and various space centers to conduct, and televise, Space STEM programming.

6.2.2 The Backstory of STEAM

Since the inception of the STEM concept in 2001, proponents of the arts, such as electrical engineer, computer scientist, graphic designer, artist, and educator John Maeda, have relentlessly fought to incorporate an "A" for Art in the STEM acronym. Science, Technology, Engineering and Mathematics (STEM) has therefore become Science, Technology, Engineering, Art and Mathematics (STEAM). Maeda's philosophy of integrating technology, education and the arts into an amalgam of creativity and innovation has its origin in his own synthesis of software development with traditional artistic methods, which laid the groundwork for interactive motion graphics.

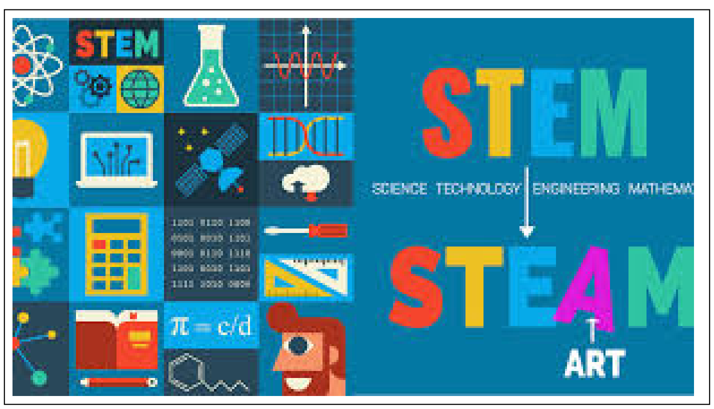


Figure 6.2: STEAM poster (Invitada, 2019).

As former Professor of Arts and Sciences at MIT, Associate Director of Research at MIT Media Lab, founder of the MIT Aesthetics and Computation Group, and former President of the Rhode Island School of Design (RISD), it is Maeda's considered opinion that artists are familiar with navigating the terrain of chaos and uncertainty in their processes. Therefore, they serve as great partners in the communication of scientific research and in the navigation of the scientific unknown.

Maeda has toured the world since 2008 to advance the concept of STEAM based on his

Figure 6.3: John Maeda in 2010 at the RISD Museum (Lamont, 2010).

conviction that scientists need art and artists in their professional lives in order to invent and innovate successfully; that for inventions to occur, scientists must embrace the art world.

Additionally, Maeda champions the role that artists and designers play in the 21^{st} century creative economy based on his belief that the current economy is built upon convergent thinkers; those who execute things, get them done. In contrast, artists and designers are divergent thinkers; those who expand the horizon of possibilities. Superior innovation comes from bringing divergents (the artists and designers) and convergents (science and engineering) together to meet the rigors of a competitive global economy (Lamont, 2010).

"With all that we have to address in the world - warming continents, fluctuating economies, monstrous cities - pursuing scientific questions in tandem with artists and designers may not seem like conventional wisdom. But given the unconventional nature and scale of the problems we face today, there is real value to be gained from collaborations that bridge the best talents we have in both the quantitative and qualitative domains. Artists and designers are the ones who help bring humanity front and center, make us care, and create answers that resonate with our values."
- John Maeda (Maeda, 2013)

On the 49^{th} anniversary of the Moon landing, 20 July 2018, the United States House of Representatives introduced the *STEM to STEAM Act of 2017* as Bill HR 3344 (a new amendment to the STEM Education Act of 2015), that required the National Science Foundation to integrate art and design into STEM education curricula. It was not acted upon during that Congressional session and was reintroduced as the *STEM to STEAM Act of 2019*, Bill HR3321.

As of 18 June 2019 the text specifically adjusts the bill to add *"The integration of art and design in STEM educational programs"* and *"design and testing of programming that integrates art and design in STEM education to promote creativity and innovation"* (Langevin, 2019)

The proponents of the STEAM movement seek to transform research policy by incorporating art and design into STEM for the integration of art in K-20 curriculum, to influence employers to hire designers and artists to drive innovation based education, to support the critical role that art plays in the education system itself and also in the economy of the United States. The bill has been referred to the Committee on Science, Space, and Technology where it currently awaits action. The STEAM educational programs are set to nurture the next generation of creatives, and become the consummate platform to drive polymathic Art/Science crossover education.

6.2.3 The status of STEAM

The addition of art and design in the STEM curriculum is a major accomplishment, and a hot topic for artists, designers and educators. Many opinions have been offered, along with studies conducted and published in the academic arena. To quantify the influence of art in the STEAM curricula using statistical data, Robert Root-Bernstein analyzed the benefit of students having artistic skill sets.

6.2.3.1 The Root-Bernstein STEAM Research

A paper published by educationalist Robert Root-Bernstein in 2015 addresses the subject of the ability of art to foster creativity in STEAM education, and its influence on scientific innovation. Root-Bernstein concludes that arts and crafts can provide students and professionals with (Root-Bernstein, 2015):

- mental skills such as observing, imaging and abstracting
- sense related, manual dexterity and manipulative skills
- analogies that provide novel approaches to solving STEM problems
- experience with materials, structures, phenomena and techniques
- practice with the creative process, and
- recreation to relax and re-energize their minds.

It was not only altruism that drove the educational revolution towards gender, race, class and geographic inclusion in the science and technology fields; rather, it was the realization that STEM occupations drive economic growth and prosperity. STEM projects also address societal problems, global challenges and create additional employment in areas that are seen as being crucial everywhere. As a consequence there are additional societal benefits in training a greater number and a greater diversity of the next generation to innovate, as each generation produces centers of excellence, and iconic role models for the next to emulate.

6.2.4 The role models of STEAM

Mary Golda Ross, the first Native American female aerospace engineer, and Mae Jemison, the first African American female astronaut in space, did not have the advantage of a STEAM educational program in their youth and few role models, which makes their endeavors to obtain an education and their outstanding contributions to the space sciences all the more extraordinary. They are both exceptional role models for space science and strong proponents for STEAM education.

6.2.4.1 Mary Golda Ross

The traditional Cherokee belief that children of both genders should be educated equally paved the way for Mary Golda Ross to become the first female Native American rocket scientist (1908-2008). The great, great granddaughter of Cherokee Chief John Ross from Oklahoma, Ross obtained a mathematics degree and joined Lockheed Aircraft Corporation in 1942 on the design team of the P-38 airplane. By 1952, Ross had obtained an engineering degree, studied aeronautics, missile and celestial mechanics and was hired at Lockheed's nascent Advanced Development Program, the only woman and the only Native American (Viola, 2018).

Over the years, she worked on the Agena rocket, and the Poseidon and Trident missiles. She also helped write NASA's Planetary Flight Handbook and worked on preliminary concepts for flights to Mars and Venus. Even today, however, much of her work remains classified, keeping the full extent of her contributions still unknown (Society of Women Engineers, 2018).

A strong STEAM supporter, Ross was a Fellow of the Society of Women Engineers, worked closely with the American Indian Science and Engineering Society (AISES) and the Council of Energy Resource Tribes (CERT) to expand their educational programs, and CERT named its highest award after her. She was inducted into the Silicon Valley Engineering Hall of Fame in

(a)

(b)

Figure 6.4: (a) Mary Ross holds the 1986 plaque for the Council of Energy Resources Tribes' *Mary G. Ross Special Achievement Award* (Society of Women Engineers, 2018); (b) The head side of the 2019 US Mint $1 dollar coin features Sacagawea, named after the Shoshone translator and guide for the Lewis and Clark Expedition in 1804. The reverse side honors native Americans in the space program (United States Mint, 2019).

1992, and endowed a scholarship to Women in Science.

The design for the 2019 US $1 Sacagawea coin honoring Native Americans in the Space Program (shown in Fig. 6.4(b)) features Ross (Cherokee), astronaut John Herrington (Chickasaw), and flight controller Jerry C. Elliott High Eagle (Osage/Cherokee). Herrington crewed the International Space Station in 2002. Elliott plotted the re-entry of the troubled Apollo 13 mission and received the Presidential Medal of Freedom for his role in saving the astronauts (United States Mint, 2019).

6.2.4.2 Mae Jemison

Mae Jemison became the first woman of colour in the world to enter space when she flew aboard the Endeavor in 1992. A chemical engineer, medical doctor, and historian, Jemison joined the NASA astronaut corps in 1987. She orbited the Earth as a mission specialist aboard the Space Shuttle Endeavor's Spacelab J STS-47 (Fig. 6.5). Within her eight-day, 127 orbit mission, Jemison participated in 44 Japanese and US life science and materials processing experiments.

Figure 6.5: Mae Jemison aboard the space shuttle Endeavour in the Spacelab Japan science module in 1992 (Eschner, 2017).

In an interview Jemison recognized that she is not the first woman of color with the skill set, the ability and the desire to work in space, only the first chosen by NASA.

> *"As a kid I was irritated that the astronauts were always white males. It was really quite irritating that if aliens were to run into them that they wouldn't recognize the full beauty of our planet and all the people on it."*
> - Mae Jemison (Eschner, 2017)

As a child who always loved the arts, dancing, and acting, Jemison branched out after she left NASA in 1992 to become an actress, a consultant for space related films, and a thought leader on how the interplay between arts, science, and sci-fi as a genre can carve out a space for often-excluded voices. Jemison's IMDB credits are as an actor in *Star Trek Next Generation* (1993) and *No Gravity* (2011), as a technical consultant in six episodes of the *Mars* TV series (2018), and an additional 24 credits appearing as herself in television documentaries or on screen interviews from 1993 till current day (IMDb, 2019*c*).

Figure 6.6: Jemison portraying Junior Science Officer Palmer with actor Levar Burton as Geordie Laforge in *Star Trek: The Next Generation*, in the season six episode *Second Chances* in 1993 (Space.ca, 2016).

The value of Star Trek for Jemison as a youth was that it presented a hopeful future, where the variety of astronauts were more than that of just white men. Also that Star Trek, even as a fictionalized science, nonetheless served as a mechanism for Earthlings to observe the effects of their society influenced by technology and that their technology continues to be influenced by societal values (Space.ca, 2016). It was the Utopian promise of diverse societies in peaceful coexistence with each other whilst exploring space that buoyed Jemison during her career, and also led to her precedent-setting global transdisciplinary initiative *100 Year Starship*:

> *"100 Year Starship is about fostering an environment where radical leaps in innovation can occur now, using the platform of human interstellar travel to push the boundaries of technology and knowledge, because we believe that pursing an extraordinary tomorrow will build a better world today.."*
>
> \- Mae Jemison (Jemison, 2013)

The media arts has overlapping platforms across its entertainment genre, each with its own audience. Margot Shetterly wrote the book *Hidden Figures* in 2016 to celebrate the life of African American Katherine Johnson and other female "computer" mathematicians who calculated orbital trajectories and flight times relative to the position of the Moon in the build-up of the flights into space.

Figure 6.7: From Left to Right: Michio Kaku, Ronke Olabisi, Anne Wojcicki, Kimberly Bryant, Jedidah Isler, Debbie Sterling, Diana Albarrán Chicas, and Mae Jemison photographed by Amanda Demme for *Vanity Fair* magazine in celebration of the release of the movie *Hidden Figures*, released 6 January 2017 (Vanity Fair, 2016).

Hidden Figures was developed into a film script in 2017. The film received critical acclaim and garnered Oscar Nominations for Best Picture, Best Supporting Actress, and Best Adapted Screenplay. It also earned 4 nominations at the National Association for the Advancement of Colored People (NAACP) Image awards, and was ranked in the top 10 films by the National Board of Review.

The book, the film, and women in science were further contextualized in *Vanity Fair* Magazine in 2017, which profiled the diverse new role models in STEM by interviewing women in science as well as theoretical physicist Michio Kaku. Photographer Amanda Demme further memorialized the subject by creating a photographic tableau which harkens back to the *Hidden Figures* ambiance (Vanity Fair, 2016).

> *"My task is to get deep thinkers involved who have never worked with space exploration, because they'll look at things in a unique way. We have people who have expertise in areas from relativistic physics to textiles to anthropology to the microbiome. We look at how the arts and sciences prod each other - and how these ideas can be used to enhance life on Earth"*
> - Mae Jemison (Vanity Fair, 2016)

As an advocate for arts and science education, Mae Jemison is a 21^{st} century polymathic icon for STEAM. She positions herself at the forefront of integrating physical and social sciences with art and culture to solve problems and foster innovation. Jemison also leverages her experience as a physician, engineer, and social scientist to build global initiatives that generate radical leaps in knowledge technology and social responsibility (Jemison, 2019).

6.3 The Sustainability of STEAM

In terms of STEAM going forward, Mae Jemison is a disruptive force to be reckoned with. Noting the value of portraying role models to the young, Jemison has intervened to expand the scope of the STEAM platform to include Vanguard Stem and Conversations with Women of Color in STEM. This intervention allows education to develop alongside of topical issues, and incorporate into its curriculum not only long hidden figures, but also long hidden problematic concepts of race, class, gender and politics. Her web series and online platform are dedicated to using STEM as a tool for social justice (#VanguardSTEM) and her end game is to broaden the dialogue to ensure a vibrant, relevant and sustainable STEAM (Vanguard STEM, 2019).

In summation, the collaboration evidenced by ITACUSS and ETTAS in their efforts to manage art in space, the zeal of the disruptive tech philanthropists, and the data gathered by Robert Root-Bernstein prove the efficacy of art processes as a key factor in innovation. John Maeda's relentless push for art to be included within expanded science curricula, the phenomenal contributions of Mary Ross and the future forward vision of Mae Jemison indicate that collaborative engagement between nations to achieve sustainability of art education in the global commons is desirable, necessary and, indeed, possible.

Chapter 7

Conclusion

The Arts and Sciences, and more specifically Space Arts and Space Sciences, have become two of society's most influential disciplines, which exert a forceful influence on the social, economic, political and cultural narratives in Western society. The critical nature of those narratives is the impetus for this dissertation's inquiry into the historical relationship between space art and space science up until the present time. This examination concludes that the Art/Sci dialogue requires a paradigm shift to consolidate their agendas and reinforce their influence going forward into the next evolution of the space industry.

The problem constraining the development of the transdisciplinary critical mass that underpins such an Art/Sci paradigm shift is the lack of a cohesive strategy to synthesize the discipline-specific studies that have already been completed by artists, scientists, academics, and industry leaders. This isolated approach leaves each participant/entity unable individually to leverage their findings and effect a transformation of the Art/Sci dialogue into a disruptive force that is necessary to sustain a paradigm shift.

Analysis of the Art/Sci dialogue itself through the literature contained in this dissertation indicates that the unparalleled vivacity of the disruptive space industry, combined with the explosive drive towards space exploration has created a unique opportunity by which to amalgamate those disparate studies.

Although paradigm shifts have occurred over the millennia, such as those experienced by artists and scientists from the Renaissance to the Space Age, they are actually quite a rare phenomenon in and of themselves. Paradigm shifts constitute a sea change in the direction of a society as a consequence of historical/social/political/economic/cultural circumstances that disrupt the status quo. This dissertation's suggestion that the Arts/Sci communities marshal extant elements into a paradigm shift as an essential component of space sustainability is based on the work of iconic artists, academicians, scientists and engineers who have dedicated their careers to researching these topics.

In the prologue to Ahmed's *The Polymath*, Oxford Art History Professor Martin Kemp speaks to a paradigm shift of epic proportion as he links polymathic ability directly to the survival of humans.

> *"True polymathy involves a unique an improbable blend of incorrigible ambition, undeterability, imagination, openness and humility. And it is more vital now than ever if we are to further the cultures or mutual understanding that is necessary for the survival of the human race"*
>
> - Martin Kemp (Ahmed, 2018)

Like Kemp, the intent of this dissertation is also to link an Art/Sci polymathic paradigm shift directly and indirectly as the next logical step in human space activities. Space arts, unlike the space exploration program after Apollo 11 that was put on hold, have never stopped imagining life farther and farther into outer space. Currently, there are thousands of artists world-wide who are deeply involved inventing space art. They carry on the legacy of those artist of the distant past, and have created an untold number of art works regarding space that they fervently hope will enliven the world's appreciation of art and space.

Creativity, imagination and innovation have always been the artist's stock in trade. Innovation has become an essential element in the development of the space industry, further intertwining the historical relationship between art and science. The maturity of the space industry has opened a remarkable new dimension for space art: to provide the innovative, creative, and imaginative momentum necessary for space science and space art to boldly go.

The UN has recognized space-based technology as a driver of sustainable development, and the concept of sustainability, in all its complexity, has become the rallying cry for the reclamation of human civilization and of the Earth itself. The New Space entrepreneurial culture is particularly focused on societal inclusion and environmental concerns as an integral elements of sustainability. This emergent circumstance has provided the momentum for inculcating Art/Sci polymathic ability and transdisciplinary collaboration into the arts, space and society agendas in the global commons and is, therefore, the next logical step in the development of human space activities.

7.1 Reflections & Findings

Following is a reflection on the dissertation topics and the findings that surround the problem of building and sustaining a paradigm shift, and that are also elements that play a part in its solution.

7.1.1 The Creative Imperative & The Polymathic Legacy

The drawings and carvings of the first cave artists exhibit human beings' enduring fascination with space. The polymathic legacy of early astronomers illustrates the creative imperative of scientists to express themselves through the arts. But perhaps the most enduring legacy is the polymathic outlook as a standard of scholarship in conceptualizing the arts and sciences. The advent of the Space Age has demystified the historic dichotomy between the arts and sciences, via transdisciplinary collaborations, and in doing so it has also highlighted the necessity of polymathic abilities spanning the Art/Sci disciplines in the current space industry. The phenomenon of the polymathic mind is receiving acclaim as space technology is embracing both specialized and generalized knowledge and skill sets.

7.1.1.1 The Space Arts Genre

Space artists are benefitting from what space technology now offers: better equipment, more data for artistic interpretation, never before seen locations from which to draw inspiration, increased access to space itself, and increased impetus to produce art for space. Astronauts and scientists are expanding their ability in the arts professions. The purpose of space art to amaze, inspire and instruct has never been as replete as now. The history of the space artists and their legacy demonstrates the concept that the horizons for space art have always been and will always be endless. The caveat here is the necessity to sustain and grow the discipline by elevating the position of the arts and of artists in society by providing economic feasibility for art as a career choice.

7.1.2 The Art/Sci Polymathic Phenomena

This dissertation has presented many iconic individuals through-out time whose lives bear witness to the veracity of polymathic endeavors for the love of art, science and society. The most important ingredient and the most enduring element that underpins the Space Arts and Space Sciences is the imperative to practice art itself and the curiosity that drives scientific inquiry. Both qualities stem from natural instincts inbred in humankind and, as such, are in limitless supply, as evidenced by the stubborn perseverance of the creative imperative throughout some extremely tempestuous epochs in human history.

The purpose of including the biographies of famous Art/Sci practitioners is to humanize and show the diversity of those who create the technology of space applications for the end users who will pay for a large part of that space technology and will become dependent upon it. Additionally, this will further reveal the fulsomeness of the Art/Sci polymathic experience so that it may become useful to the following generations who have the responsibility of ensuring the continuance of the space age benefits in their day to day reality.

7.1.3 A Culture of Transdisciplinary Collaboration

Transdisciplinary collaboration utilizes various branches of knowledge to create a vibrant culture that fast-tracks outcomes between practitioners of the arts and sciences. Art/Sci collaboration is not new, it has been occurring in various pockets such as the Massachusetts Institute of Technology (MIT), JPL, CERN, NASA, the Cosmic Evolution Survey (COSMOS), *Leonardo*, Ars Electronica, and at various universities, museums, and conferences since the 1960's. With the sustained development of space technology and its commercial applications, collaborations are providing a context for polymathic overlap and thus, becoming a nexus of creativity and innovation and are thereby creating a whole new class of creative professionals in the space industry.

Art/Sci integration is bearing fruit. Artists are become effective researchers in the design of the content of space missions, are providing input into the outcomes for end users and beneficiaries, and in this fashion are promoting a socially robust science. Art/Sci collaboration is having its desired effect, scientists and engineers are expanding their design strategies using art techniques and approaches, and space art is becoming increasingly more complex and wider in scope with the input of scientists and engineers.

Additionally, the media arts have created space science superstars, and provide a platform to share those breath-taking images that have been captured. The on-screen time afforded all levels of participants in the space community in film, television and video is staggering. Space agencies and the commercial sector are becoming more media-savvy, enabling media producers to invent yet new platforms (with the collaboration of engineers), on which to feature the newest space science and commercial applications to amass an even larger viewership.

The value of investigating the participation of the media arts is to celebrate the ingenuity of its creators, and also provide contrast to documentary films and movies whose glossy images, well-worded narration and evocative music create a scripted story line of space edited to fill a specified time slot. While many are truthful to history and science, others are truncated and lack context. Many are made primarily to shock, awe and entertain with incredulous plots that serve the needs of the entertainment industry alone. Media's influence on audiences with its portrayal of space art and space science is unsurpassed by any other industry and requires an ethical approach and a consensus on industry best practice.

7.1.4 The Global Commons & Global Education

As Space Art enters the global commons it requires regulation, legislation, curating, conservation, funding, and governance from a consortium of entities. A new arena of legal expertise in Space Art needs to be established. Otherwise, space art will become space junk, and space advertising may eventually win the day. Additionally, polymathic study is expensive, there is a necessity to legitimize the inclusion of art in the STEAM curricula globally, so that it can formally be funded and evolve into a disruptive educational platform to ensure polymathic studies in space art and space science for future generations.

7.1.4.1 The Paradigm Shift

A paradigm shift is analogous to a living, breathing entity in a constant state of flux. It has many complex non-stable facets that affect its development and affect the expected outcomes. Therefore it needs to be nurtured and monitored as elements constantly change. The continuing Art/Sci inquiry that forms the nexus of the paradigm shift will need to constantly address/revise the following topics:

- Can operating in the fresh landscape of the revolutionary New Space technology, disruptive philanthropy models, advanced STEAM education, and a global focus of environmental and robust space science ensure sustainability or obtain the critical mass necessary to significantly effect a paradigm shift in modern Art/Sci dialogue?
- Will the growing emphasis on polymathic tendencies and interdisciplinary fusion within the Art/Sci community sufficiently nurture the creative instincts that provide the innovation which drives the space community?
- How can the concepts of transdisciplinary collaboration become as widely accepted as needs be by the majority of decision makers in the space community?
- Can the models developed by Philippe, Triscott, Pell, Malina through ITACUSS, ETTAS and Leonardo/ISAST be used as a basis for creating a revolutionary, disruptive and collaborative platform for space art to be made, monitored and appreciated in the global commons of space?
- Can the extant communities marshal their forces timeously to exploit the unprecedented resurgence in space exploration?
- And can that paradigm shift be able to effect the agenda of the space arts and space science disciplines going forward in the next evolution of the space industry?

These interrelated topics indicate that the creative nexus of the Art/Sci disciplines has never been as replete with possibility as now, as artists continue to extrapolate from the vast arena of space data to expand the arts, humanities and cultural expression relative to space exploration. Especially now that the global interest in space exploration and potential of future colonization has reached a fever pitch, the time is upon the practitioners of Visual Arts and Space Sciences to focus on coalescing the benefits of disruptive space technologies and polymathic skills applied in transdisciplinary fields.

7.2 Recommendations

The transdisciplinary ability of the Art/Sci dialogue to exert significant influence going forward has never been more critical, or as probable than today, as we stand on the precipice of game changing space science applications. Toward that end, recommendations to achieve the aim of using the arts as innovative and exciting change agents include:

1. Greatly expanding existing platforms and engineering new platforms for the visual arts and the media arts to reach ever-widening audiences with their ability to contextualize the narrative of space art/space science.
2. Obtain a global consensus on models of governance, ethics, conservation, funding and curating of space art. This would require first establishing a platform to encompass international and interdisciplinary leadership and a consensus on best practices. This endeavor requires a new genre in global law, that of space art which requires professionals to specialize in drawing up and implementing space art legislation.
3. The manifestations of the Art/Sci dialogue itself (its conferences, its papers, its art exhibitions, its podcasts, books) be published widely, publicized via media productions and inculcated in educational curricula.
4. Support the concept of New Space disruptive philanthropic giving and encourage further participation on a grand scale among high-net-worth individuals, corporations and entities whose mandate includes the elevation of education, arts, sciences, and society. Extend the capability of the public to invest in space with many more crowdfunded initiatives.
5. Legislate STEAM education nationally, and provide polymathic education and cultural cross-pollination globally to upskill subsequent generations who will be creating the Art/Sci arena in the future.
6. Encourage scholastic endeavors via scholarships for space artists, space filmmakers, and space scientists/engineers. Develop art/space camps with international participants so that they become commonplace. Embed polymathic education and art/space camps at all levels of education with varying degrees of sophistication, from kindergarten to post graduate work.
7. Fund more traveling art exhibitions, books, journal publications and video screenings featuring space art/space science to serve as social platforms to bring together diverse actors across the spectrum of arts, sciences, and society. These encounters enable communication between various actors in the art and space communities by creating common ground for international appreciation of the arts.
8. That engineers/scientists assist artists to devise equipment, instruments, tools, and materials for space artists to utilize in the making of art on Earth, in space, on the Gateway, on the Lunar colonies and on Mars. Additionally, develop space art museums

for the future to archive, protect and curate artworks for exhibitions wherever people reside.

9. Encourage "smart art" for use in space, for example, satellite/sculptures that have dual function as works of art and are also sensors, rather than art that merely decorates satellites, or sculptures that eventually become space debris.
10. A Nobel prize category be established for visual artists as it is for literature. Further inculcation of the Art/Sci potential in international governance, such as the United Nations and its various divisions. That Space Artists and Art/Sci polymathic minds are offered a seat at the table in global think tanks and other international fora.

7.3 Further Studies

Categories for further studies emanating from the research presented in this dissertation that can widen the discourse are:

1. Further investigation into the global cultural paradigms that enhance or restrict the production of space art/space science.
2. Further investigation into the concept that overlapping polymathic ability in both the arts and sciences is instrumental in nurturing two essential qualities necessary for meaningful artistic expression and that also drive the space industry: creativity and innovation.
3. An investigation into what the creative nexus between the arts and sciences has produced and is currently producing in non-Western cultures.
4. An investigation into synaesthesia and its effect on artists and scientists personally and professionally. To glean information on why people with synaesthesia commonly enter into either discipline and how synaesthesia effects their imagination, creativity and work processes and the veracity of their results.
5. The psychological and sociological ramifications of the Overview Effect experienced by Astronauts, and the extent of its cultural expression in visual arts, literature, music, education, politics and society at large.
6. Further mapping of disruptive global philanthropic giving trends in space arts and sciences, combined with the inclusion of lay people financing science ventures, such as the potential for crowdfunding of space and art missions.
7. The compilation of an up-to-date global data base listing innovative collaborations in the space art/space science disciplines that measures their influence on the participants

and the public.

8. An updated compendium listing both well-known and unknown Art/Sci polymathic individuals globally whose work has had an impact on current art or science disciplines. This data can then be used as a basis of scripts for future television and internet programming platforms.
9. Papers determining how scientists and engineers are expanding their design strategies using art techniques and approaches. Space art is becoming increasingly more complex and wider in scope with the input of scientists and engineers. What are the qualitative and quantitative results of art informing science and science informing art?
10. Further study on how art, play and entertainment affects the lifestyle and well-being of astronauts in space.
11. Enhance the possibilities for astronauts to draw, create graphic art, sculpt, paint, make music, and expand the use of 3D printing for art purposes in space environments..

This dissertation's intent is to expand the knowledge base of the art and science disciplines by focusing on strands of inquiry specific to space art and space science, then weave them into a matrix that utilizes the creative imperative, polymathic ability, and transdisciplinary collaboration. This inquiry is directed to space artists and space scientists to highlight the critical nature of their work, and to inspire practitioners in both disciplines to meet the challenges of the forthcoming developments on Earth and in space.

Regardless of the passage of time since the first cave artists to the present-day space artists, the preoccupation of humans to comprehend space in an effort to influence their destiny remains the same. Space scientists today find themselves involved in the same activity as space artists of ancient times: the active study of space. Three interrelated constants throughout human history that underpin space art and space science are the fascination with space, the need to express art, and the quest to explore. These three constants are the keystones upon which space artists and space scientists can rely to navigate future interactions, and are the elements that concretize the adamantine bond between Space Art and Space Science.

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