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KEPLER SPACE INSTITUTE

DEDICATION

We dedicate this issue of the Journal of Space Philosophy to the needed research for the question, "How do we define preferred future goals and characteristics for humanity for the planning of the Space Epoch?"

See the featured article by Dr. Lawrence G. Downing.

All our thoughts today are dedicated to the solution of the COVID-19 global crisis.

Bob Krone and Gordon Arthur

PREFACE

This Spring 2020 issue of the *Journal of Space Philosophy* goes to press as the world suffers what may turn out to be the worst biological pandemic in Earth's history. The coronavirus has spread rapidly around the world with no vaccine to counter it. It is an unseen human enemy causing illness and increasing fatalities. Since 2012, this journal has addressed many natural and human threats to humanity that Space may be able to ameliorate or resolve. This is a new threat that originated on Earth with no known Space solutions today. This issue includes an article by Louis Kauffman and Joel Isaacson on Recursive Distinctioning. Readers will see a possible scientific link between biological viruses and RD at the end of their article.

Also in this issue, we begin a new academic subject that will appear in our future courses, programs and research. The basic research question for that subject is "How will Space settlers need to adapt biologically, mentally, and socially to living and surviving in Space?"

The feature article is "Long-Term Space Inhabitants: Their Needs, Care and Support," by Lawrence G. Downing, DMin.

Dr. Downing is one of the founders of Kepler Space Institute (KSI), is KSI Director of Space Faith, and is a member of the KSI Graduate Faculty. Following are a few research questions he included in his article:

> What are the most efficient and effective methods to sustain and enhance life as humans make their way toward and into the vacuum of space? What are the moral and ethical implications incumbent upon those who are responsible for the care and protection of intelligent life-forms? What adaptations are necessary to enhance the survival of those who live beyond Earth? What are the mechanisms necessary to maintain healthy individuals encapsulated in a mechanical contrivance, and what are the strictures that will guide the behaviors of those who are thrust on the long journey to a chosen destination?

Bob Krone and Gordon Arthur
Editors, Journal of Space Philosophy

JOURNAL OF SPACE PHILOSOPHY

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Access to the Journal of Space Philosophy and free downloading of its articles is available at www.keplerspaceinstitute.com/jsp. Anyone on Earth or in Space may submit an article or Letter to the Editor to BobKrone@aol.com.

Notes from the Chair

By Gordon Holder, VADM, US Navy (Ret),
Kepler Space Institute Chairman of the Board

We publish this issue of the *Journal of Space Philosophy* in the Spring of 2020 when the coronavirus is crippling humanity on Earth. It is a direct and immediate threat to citizens around our globe. Its impact is very similar to other issues, such as climate change, ozone levels, and other global threats that require leadership collaboration across national borders to achieve remedies and solutions. We know that Space holds some of the secrets for those solutions.

The Kepler Space Institute is dedicated to advancing humankind in all areas, and we believe that exploration and settlement of other planets will aid all humanity.

Enjoy this latest issue of the Journal of Space Philosophy.

Letters to the Editor

Some Comments on the Coronavirus Pandemic

By Yehezkel Dror

1. As of now, the global coronavirus pandemic is child's play compared to the 1918-20 Spanish Flu, which killed more than 50 million people from a much smaller global population—without long-term consequences.

2. Of the coronavirus, little is known. The numbers of sick and recovered are wild guesses; the duration of post-disease immunity is unknown; no vaccination is in sight; no effective treatment is known.

3. Ergo, no half-reliable model of coronavirus pandemic trajectory can be constructed. Pending more knowledge, only intuitive improvisation is the rule.

4. Unlike many other global issues, the United States is not leading the fight against the global coronavirus pandemic. Strange relations between the president and medical-epidemiological experts, the absence of national health insurance and institutions, hostility towards the WHO, and a federal system preventing a unified national policy make many countries wonder.

5. But the vast majority of countries share one dangerous characteristic: politicians were not really prepared for coping with serious global issues, as also demonstrated by their mishandling of climate change. This bodes ill for much more fateful global challenges that are sure to be posed by the emerging metamorphosis caused by potentially very dangerous, as well as promising, science and technology.

Recommended Reading

Crawford, Dorothy H. *Viruses: A Very Short Introduction*. 2nd ed. Oxford: Oxford University Press, 2018.

Dror, Yehezkel. *Steering Evolution: Eighteen Theses on Homo Sapiens Metamorphosis*. New York: Routledge, forthcoming.

McMillen, Christian W. *Pandemics: A Very Short Introduction*. Oxford: Oxford University Press, 2016.

To achieve internal tranquility in wild times, which is needed for prudent judgment and action, I recommend to you:

Seneca, Lucius Annaeus. *Seneca's Letters from a Stoic*. Translated by Richard Mott Gummere. Mineola, NY: Dover Publications, 2018.

Editors' Notes: We are pleased to provide readers with comments on the current global COVID-19 crisis by one of the world's leading Policy Scientists, Professor Yehezkel Dror, who is also a deep thinker on human evolution. ***Bob Krone and Gordon Arthur*.**

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Introduction by the Editors

We have been blessed throughout the publication history of the *Journal of Space Philosophy*, beginning in 2012, with the volunteer service of 42 professionals in the Space community to act as reviewers and consultants to our authors. They have been listed in the final article of each published issue. We are proud to announce with this letter the addition of our latest Senior Consultant, Dr. Bernd Anton Schmeikal.

This Letter to the Editor is about Dr. Schmeikal.

Bernd Anton Schmeikal, born May 15, 1946, is a retired freelancer in research and development, qualified in Sociology with a treatise about cultural time reversal. He is a real maverick, still believing that social life can be based on openness and honesty. As a PhD philosopher from Vienna, with a typical mathematical physics background, he entered the Trace Analysis Group of the UA1 Experiment at CERN, under the leadership of Walter Thirring, in 1965. This was in the foundation phase of the Institute for High Energy Physics (HEPhy) at the Austrian Academy of Science.

He has always been busy solving fundamental problems concerning the unity of matter and space-time, the origin of the HEPhy standard model, and the phenomenology of relativistic quantum mechanics. In the Sociology Department of the Institute for Advanced Studies (IHS Vienna), he helped James Samuel Coleman to conceive his mathematics of collective action as a cybernetic system, and he gave the process of internalization of collective values an exact shape. He implemented many transdisciplinary research projects for governmental and non-governmental organizations, universities, and non-university institutions, and several times he introduced new views and methods.

He founded an international work stream that, for the first time, worked under the name of the Biofield Laboratory (BILAB). Although close to fringe science and electromedicine, the work of BILAB had a considerable similarity to the Biological Computer Laboratory run earlier by Heinz von Foerster. Lately, he has applied Foerster's idea of a universal relevance of hyperbolic distributions (Zipf's law) in social science to the labor market. This signifies a last contribution to the research program of the Wiener Institute for Social Science Documentation and Methodology (WISDOM) under the sponsorship of the Austrian Federal Presidential Candidate Rudolf Hundstorfer.

Dr. Schmeikal is convinced that a unity of science and culture can be achieved, but that this demands more than one Einstein. Consequently, he sought cooperation with Louis Kauffman and Joel Isaacson.

Dr. Bernd Schmeikal's review and evaluation of Joel Isaacson and Louis Kauffman's Recursive Distinctioning (aka "Nature's Cosmic Intelligence") research and papers, published in the first issue of the JSP, Fall 2012, again in the Special JSP Issue on Recursive Distinctioning, Spring 2016, and again in the Fall 2017 issue, are very valuable contributions to this forefront science investigation of Nature's Cosmic Intelligence. Dr. Schmeikal, University of Vienna Professor in mathematics, linguistics, and physics is one of the world's distinguished scholars for this special field of universe autonomous intelligence. He begins his abstract with the statement: "This paper investigates a universal creative system," and ends it with "That is to say, our universe may be a representation of Isaacson's system, and entertainingly, with his US Patent specification 4,286,330, 1981, it seems he has patented creation."

Reports on the four annual KSI-sponsored Conferences for Recursive Distinctioning, to date, can be found in JSP publications. Dr. Schmeikal's latest book publication is *Nuclear Time Travel and the Alien Mind*, published by Nova Science Publishers, New York. In 119 pages, Dr. Schmeikal tells the historic story of unidentified objects, and the knowns and unknowns of advanced space-time warping time-travel technology. He includes a September 24, 1947 top secret letter of President Harry Truman to Secretary of Defense Forrestal, authorizing research into these matters, but confining ultimate disposition to be solely under the Office of the President. Dr. Schmeikal's discussions of the impacts of the extraterrestrial mind on past Earth events give a research variable as we attempt to understand and predict future outcomes of attempts at improving humanity's prospects (see Yehezkel Dror, JSP, Summer 2015 and Kepler Space Institute, book publication, 2019) as we humans proceed with exploring, developing and building human Space settlements.

Bob Krone and Gordon Arthur
Founding and Current Editors, Journal of Space Philosophy
April 15, 2020

Long-Term Space Inhabitants: Their Needs, Care, and Support

By Lawrence G. Downing, DMin

IMPORTANCE: Science and machines make Space travel possible; humans add soul. Those who manage space travel need to be as creative to care for the humans as for the hardware.

All life forms have limitations. *Time* is one of the most persistent and consequential of these boundary points. We humans have the unique ability among all other life forms to ponder implications related to time. We are aware that we have a beginning and an end point. This knowledge affects our hopes, challenges our endeavors, and impacts how we judge options and possibilities. The way we have chosen to define time: days, months, years, minutes, and hours, loses its significance if the limits to our life span are nullified. As it is, our accomplishments and plans for the future take into account our concern and preoccupation with the span of human life.

Our treks into far Space will not diminish our concern for and the effects of time; indeed, as we set our sight into far Space, the passage of time will take on greater importance than now. Our sights include transport to places that are so removed that it will take multiple generations to reach the selected destination. Life, unlike space, is not limitless. Those who lead the way into faraway places may well not live to see these ventures to their conclusions.

Within the context of the age of the universe, the duration of an individual human's time is inconsequential. Any thought or discussion that considers a reach beyond even the most proximate planets or stars necessitates considerations that include multi-generational life on any voyage toward the places where some propose to establish human colonies. No model exists that provides guidance for such excursions. Indeed, there are those who state that such ventures are impossible. A moon colony or a settlement on Mars? Perhaps. Beyond that? Forget it! Whether it be a settlement on the moon or Mars, the introduction of humans into the space equation presents significant challenges to those who design and manage such endeavors.

The questions associated with proposals to venture beyond Earth loom large: Within the context of our physical limitations, what are the most efficient and effective methods to sustain and enhance life as humans make their way toward and into the vacuum of space? What are the moral and ethical implications incumbent upon those who are responsible for the care and protection of intelligent life-forms? What adaptations are necessary to enhance the survival of those who live beyond Earth? What are the mechanisms necessary to maintain healthy individuals encapsulated in a mechanical contrivance and what are the strictures that will guide the behaviors of those who are thrust on the long journey to a chosen destination? Should people violate established norms, either by a Singularity or by persistent transgression, what consequences will be imposed upon the perpetrators and by whom will the actions be implemented and monitored? Juxtaposed to these questions is the matter of religious systems that may guide and are important to some individuals who venture beyond Earth. Will the propagation of one's religious convictions be encouraged or thwarted? What controls, if any, will be placed to direct how one may implement a personal belief system?

When humans venture into an unknown Beyond, unfettered by factors associated with life and relationships that existed when they lived on Earth, questions of purpose, meaning, values and ethics have existential significance. From lift off to the point where a space vehicle breaks from earth's gravitational force, the mission and those who participate in that mission depend upon the application of science to assure success. It is important, however, to recognize that science does not answer questions that relate to purpose, responsibility, or human situations such as life and death.

The ability to project a vehicle and its complement of human passengers has been made possible by a synergistic application of scientific advances combined with human ingenuity, allocation of resources, and determination. The successful blending of these numerous factors has, within our lifetime, made real what had once been the stuff of science fiction and what, in their time, were irrational dreams.

We have learned to apply an eclectic collection of scientific knowledge that includes a more sophisticated understanding and application of the laws of physics, a broader view of the cosmos, and the advancement of material fabrication and design and electronic mechanisms that control much of the flight operations. We have utilized mathematics, enhanced by computers, to perform what previous generations could only imagine. Applying our vast array of knowledge and experience to a Singular project, to launch a rocket into space, has brought us to the point where we consider Space travel a common experience. Our skills and successes have brought us to the point where we are confident to place humans in our machines, to send them on extensive missions into Space, and to expect a safe return. A high priority in our space experience is to control and diminish risk factors. When men and women are passengers sent to the Beyond, concern for their well-being and survival is extreme. Ethics, morals, and values are suddenly pertinent, and they occupy an essential place in our intent to achieve a successful Space venture.

When space travel was limited to machines and mechanical contraptions, life's grand questions relating to morals, values, purpose and needs were given little, if any, thought. The introduction of the human component changed everything. Science controls the operations and function of a space vehicle; the humans aboard that craft are emotional beings with feelings, hopes, fears, desires, and needs.

It is to be expected that individuals who take the Great Venture into Space beyond space will carry with them habits, practices, beliefs, religious traditions and beliefs, expectations, symbols, and other factors common among those who live on Earth. What are the limits, if any, that will guide in the acceptance, practice, or prohibitions associated with potential adherents to the variety of beliefs or behaviors? Those from the Christian faith my believe in a responsive, relational God, a Being who makes demands and extends promise.

A Muslim may expect accommodation to face Mecca while on a journey that follows no meaningful compass location.

Individuals from the Buddhist, Hindu, and hundreds of other social and national religions may occupy a space vehicle or habitation structure. Is there accommodation on space flights for faith leaders, instructors, guides?

Are those who participate in extended space travel expected to be asexual? How will the population be perpetuated? Will test-tube babies be the norm? Who will be responsible for the care and education of those who are born? Will families form and separate as they do on earth? We can expect that, as on Earth, people will fall in and out of love. Will there be legal implications of established or broken relationships? How will property on a planet be allocated and protected?

The above is but a partial enumeration of the practical and theoretical challenges that confront those who travel beyond Earth's boundary. The individuals who manage and prepare the people who board the contrivances that propel humans toward the Beyond face challenges unlike any before. It is a phenomenal opportunity and responsibly to prepare the men and women who set upon a Singular endeavor and to assure their success and safety. The human manager's task is of equal complexity to that of those who are responsible for the design and construction of a dependable space vehicle. It is one thing to latch together diverse pieces of metal, plastic, or other construction materials. Quite another set of skills are called upon when a select group of individuals is formed to inhabit the vehicle that will carry them to places where the unknown is more common than the known. Proposals to establish permanent colonies further complicate matters.

Human habitation implies time. Time is not friendly to life-forms. The intention to establish space colonies invites us to consider the correlation that links time and mortality. We age. We become ill. Those we love and value die; as do we.

Within a community, it is to be expected that both positive and negative events will occur. Best practice mandates that individuals, prior to launch, be prepared to provide meaningful and adequate responses to events that arise within the community and that impact its residents. A space community will be populated by individuals who share the same concerns, hopes, frailties, and dreams as we who remain citizens and residents of Earth. Science may be a driving and determinant force, but, to paraphrase words spoken centuries ago, men and women do not live by science alone! Science measures, defines, and enables, but it has limits. Science does not provide succor to the weary or respond to human physical, psychic, or spiritual situations.

Janet Martin Soskice, a professor of Philosophical Theology at the University of Cambridge, in her chapter "The Ends of Man and the Future of God," states that "man" in the 21st century "seems to have been swiftly demoted from being the crown of God's good creation to being just one more creature in a line of creatures destined for extinction, just another episode in the history of nature."[1] She reminds us that in our Postmodern world, "the single individual … or the individual ivy leaf or drop of water—seems of no importance compared to the law-like generalizations that govern the whole."[2]

Those who occupy the far reaches of space, in their splendid isolation, may conclude that they, like the universe, are doomed to extinction and give up on life. When such situations arise, there is need for someone who can provide alternative thoughts to counter hopelessness and to give assurance that there is an alternative to the pessimistic scenario.

There are viable options that extend beyond scientific purview. Rituals are one example. Rituals provide solace, purpose, and meaning to human life. Celebrating a holiday brings people together to remember a past time or event. Rituals such as these perpetuate contact between the "then" and the "now." Birthdays, baptisms, funerals, holidays; these activities involve a community. When we participate in these events that transcend technology and science, we are reminded what and who we are. It is important, therefore, that a place for men and women who have the ability to respond to our fundamental humanity and its needs is included in community life, whether that life be on Earth or in Space.

Those who manage and support the individuals who are sent into Space have, I propose, a moral and ethical duty to study and implement effective and responsible action that addresses the realities that make us who we are: vulnerable, fragile human beings. Viable options are numerous, but they present a logistical and managerial challenge to implement, a challenge that one ignores at great risk.

It is not the purpose of this article to articulate the process or methods that will satisfy the requirements associated with how best to satisfy the needs of those who journey into and occupy Space. What can be said with some assurance is that humans will be humans whether they live in New York City or on the Moon. It is not unreasonable to propose that both the good and the ill will always be part of our life experience. How we respond to these factors makes all the difference in the world.

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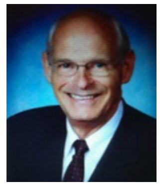
[1] Janet Martin Soskice, "The Ends of Man and the Future of God," in *The End of the World and the Ends of God*, edited by John Polkinghorne and Michael Welker (Harrisburg, PA: Trinity Press International, 2000), 82.
[2] Soskice, "Ends of Man," 82.



Editors' Notes: Dr. Lawrence Downing, DMin, after his forty years as a Minister, University professor, and author specializing on human values, ethics and moral leadership, joined the Kepler Space Institute (KSI) in its formative years as the Director of Space Faith. With this article he opens a new major research subject that KSI will pursue in its graduate curricula and in its interactions with the global Space Community. The basic research question for that investigation will be: "How do we in the 21st century on Earth define the preferred social, political, spiritual, moral and ethical status for future humanity as it settles in Space?" If a consensus can be reached on that question, it will impact the science, technology, engineering, and human factors for the design of future human Space missions. It will also hinge on Stephen Hawking's question about "whether humanity has a future." ***Bob Krone and Gordon Arthur*.**

Looking Beyond the Overview Effect

By Frank White and Kim Peart

Editors' Note: This is intended as a discussion document. We welcome responses to these ideas.

An early 1900s view of the Earth from space by W. T. Benda.

What may the Overview Effect lead to?

We suggest it leads to the next phase in human evolution. This is explored in the 2006 document, "Creating a Solar Civilization."[1] We suggest that war in space will be a threat to human survival, so we need to build peace on Earth, which will then improve security in space. The best way to build peace on Earth is to end poverty on this planet, which can happen by ensuring that all citizens on Earth can have a career, be able to work, receive a proper income, and be assured of a home. We call this a basic universal life expectation.

Ending poverty can be achieved by using the wealth generated in space to ensure that there is no poverty in human society. At the same time, we suggest that there need to be creative incentives to encourage citizens to engage in society. Building peace with creative engagement will also help to improve the human-machine relationship. Rather than fearing machines displacing humans from work, there will be ongoing collaboration between human and machine. This approach to space, where creativity displaces conflict,

[1] Kim Peart, "Creating a Solar Civilization," spacepioneers.com.au/articles/casc.html.

can only be achieved if a strong campaign for space is mobilised on Earth, which may need to be supported by ten million or more people who see the reason for space.

Clearly identifying the evolutionary step from Earth into space as essential for many reasons, will help to build the case for space. The evolutionary step to space became possible in the 1970s, but it has been delayed by half a century. The consequence of this delay is to restrict human progress to Earth alone. This needs energy to do work, which is turning the Earth into a pressure cooker planet. Considering how 20 million people marched in the first Earth Day in 1970, and 200 million people marched in Earth Day when it went global in 1990, it is quite clear that environmentalism is a political force to be considered.

Beyond the COVID-19 pandemic, environmentalists and climate crisis campaigners will be multiplying their efforts to save the Earth. By clearly demonstrating that space is essential to winning back a safe Earth, the fight for space can be presented to the global environment movement. At present environmentalists are at best disinterested in space, and at worst, actively hostile to space development. There will be political pressure upon nations to direct all their funding to the welfare of the Earth. This campaign will impact politicians, and impact space funding. As a consequence, the very area of activity with space that can save the Earth, may be crippled by Earth campaigners. This will especially be the case should our world dive into a depression, and any funding become barebones.

Environmentalists do not mention this, but for half a century, they have totally failed to keep this Earth safe. The blame is always directed toward others. If we can show the evolutionary necessity of space development, environmentalists will be invited to engaged with natural law.

Dr Jennifer Bolton presented a joint paper at the International Astronautical Congress in Washington, DC in October 2019, pointing out how space development is the way to win back a safe Earth.[2] Our paper suggests that space-based solar power can be used to deal with the carbon crisis on Earth, and that a space sunshade can be deployed to cool the planet.

China is now looking to build solar power stations in space.[3] Anyone interested in a future in space, could support a campaign to convince national governments to cooperate on a global space power program. An international space power program can become the first step toward peace on Earth, and avoiding war in space, which could lead to a space junk cascade that harms progress with space development, if not make space options near

[2] Jennifer A. Bolton and Kim Peart, "Fixing the Global Carbon Crisis with Space Development," stargategrid.forumchitchat.com/post/presentation-fixing-the-global-carbon-crisis-with-space-development-oct-2019-10357881?pid=1310145993.

[3] www.thestar.com.my/news/regional/2019/12/02/china-to-build-space-based-solar-power-station-by-2035.

impossible[4] Another fear of nations will be the prospect of an opponent dominating space and deploying kinetic weapons, which could be made in space from space resources.[5]

A kinetic weapon the size of a telegraph pole made of metal cannot be stopped, and upon impact, it would have the power of a nuclear bomb, and without radiation fallout. The fear of kinetic weapons may well trigger conflict among leading space nations, to ensure that they will not be threatened from space. International cooperation with space solar power to save the Earth would also have the knock-on effect of opening space for the benefit of all nations, and also deliver peace in space.

Where there is now a clear understanding of ecology on Earth, in space the relationship between life and machine takes on a whole new meaning, and it may be referred to as a cosmic ecology. Developing the concept of a cosmic ecology may help to communicate the difficult concepts involved in surviving in space. Cosmic ecology can be presented as the way we achieve a mature phase in our evolutionary progress, whereas at present on Earth, we are trapped in a perpetual growth phase that harms the environment. We can demonstrate how machines can be built in space factories that can be used to clean plastic trash from the oceans or built in factories on Earth that are powered by space-based solar power. With very little imagination, it is possible to demonstrate how space development can be put to work to solve every problem on Earth. Space development can therefore be presented as an essential green activity in a society practicing cosmic ecology.

Within the past five years we have seen three super catastrophes on Earth, with the loss of half the Great Barrier Reef in two marine heatwaves, and now more coral being killed in a third and worse marine heatwave, extraordinary fires that raged through Australia for half a year, and now the COVID-19 pandemic. Look forward five years, and consider what super catastrophes may lie ahead, with other pandemics, further loss of ocean coral, more fires raging across continents, the prospect of sudden sea level rise from the collapse of polar ice, heat spikes that increase in intensity and kill more people, animal and crop deaths, more severe floods, and more severe ocean storms.

We need the tools provided by space development to win back a safe Earth.

We need to sell the necessity for space to the people of Earth.

If the global space community will not sell space to the people of Earth, space options may be lost to the finer arts of campaigning by environmentalists.

The Overview Effect springs out of campaigns by nations to conquer space. It can also be seen as an essential inspiration for a campaign for space. Space campaigners can directly connect with a future in space, even while on Earth. They can do this through learning to use remote control systems with robots, as this is how much space work will proceed, even from Earth. A space campaign can seek to launch a satellite where mini robots can be operated by users on Earth, and to see the Earth from space through the

[4] en.wikipedia.org/wiki/Kessler_syndrome.
[5] en.wikipedia.org/wiki/Kinetic_bombardment.

cameras of the robots, which users are able to move around by remote control. In this way, space campaigners will be able to access a direct overview experience from Earth, and they can decide for themselves what they make of it. Some of this may find inclusion in a fourth edition of The Overview Effect.

While the world is in pandemic lock-down, a space campaign can be prepared to hit the streets of cities around the World, a space day to celebrate space. Many people joined the first Earth Day in 1970, inspired by the 1968 Earthrise photo, but the global environment movement has maintained a total focus on the Earth. This total focus on the Earth has failed to keep this planet safe. Only with a strong campaign for space can we hope to build an irreversible momentum for space. We need to demonstrate how space can be put to work to fix all strife on Earth. As we secure our future in space, we can also work toward a safe Earth. These are two hands that must work together, or both may fail, putting human survival at risk. They are the two wings of the same bird. We do not know what kind of world we will get after the pandemic, or if space will be put aside in the face of more pressing needs on Earth. For space to be seen as relevant by the people of Earth, by politicians, by governments, we need to sell space as essential, and to win strong support for this. In the spirit of the Overview Effect, we need to be able to see where we must go, and to connect with this future. As we define a cosmic ecology, we can also map out a management plan for the Solar System as a whole. With a sustainable industrial presence in space, we will then be able to design for an ecologically sustainable human presence on Earth.

We are half a century late in rising to the challenge of our evolutionary survival in space. Do we have to lose another half century, only to find we have left our run way too late? Our cosmic survival may now hinge on individuals seeing the need to act on space.

Beyond the Overview Effect lies our evolutionary survival in space.

Earth is in space.

Related Ideas and Quotations for Discussion

“It is not the strongest of the species that survives, nor the most intelligent, but the one most responsive to change” (often attributed to Charles Darwin).

“Earth is the cradle of humanity, but one cannot remain in the cradle forever” (Konstantin Tsiolkovsky, in a 1911 letter).

“It is our duty to survive” (James Lovelock, *The Vanishing Face of Gaia: A Final Warning*, New York: Basic Books, 2009, 86).

“We can no longer expect Mother Earth to take care of us—the planet is ours to run, and we can’t retreat from the responsibility to run it wisely. It would be good if our descendants looked back on this challenge we face now as the one that allowed us, as a species, to grow up” (Wally Broecker, *Fixing Climate*, New York: Hill and Wang, 2008, 223).

"A unique day in American history is ending," Walter Cronkite intoned on the CBS Evening News on April 22, 1970. The inaugural celebration of Earth Day had drawn some 20 million people to the streets—one of every 10 Americans and a way bigger crowd than the man who had dreamed up the occasion, US senator Gaylord Nelson, had anticipated.

"Why We Won't Avoid a Climate Catastrophe," article by Elizabeth Kolbert, *National Geographic*, April 2020, www.nationalgeographic.com/magazine/2020/04/why-we-wont-avoid-a-climate-catastrophe-feature/. This issue of *National Geographic* presents both an optimistic and a pessimistic guide to life in 2070.

"The important thing to understand about Earth Day is that it was not the celebration of the birth or maturation of the environmental movement in the United States, in the sense that the first Fourth of July was the celebration of the birth of a nation. It wasn't the environmental movement that created Earth Day, but vice versa. The old conservation movement had historical roots that went back more than a hundred years. The groups and organizations that would be identified with the environmental movement after Earth Day—the Sierra Club, Friends of the Earth, ZPG, and so forth—all existed before. Yet there was no environmental movement in the United States before Earth Day or even on Earth Day. It was only after Earth Day that the movement began" (Lewis J. Perelman, "The First Earth Day: 1970", *Krytic L*, April 20, 2015, medium.com/krytic-l/the-first-earth-day-1970-13a5493df5a2). The quote is from Perelman's book, *The Global Mind: Beyond the Limits to Growth* (New York: Mason/Charter, 1976).

Apollo 9 astronaut Russell L. Schweickart shared with White, "My interest is in elevating the vision of the community of people on the surface to the importance of this [space] environment, and the way it's going to affect the future of humanity. We have the opportunity to wipe out life on this planet, and we can also see it as a whole. The technology available allows both" (Frank White, *The Overview Effect*, Boston: Houghton Mifflin, 1987, 201).

"It is the hope of those who work toward the breakout from planet Earth, that the establishment of permanent, self-sustaining colonies of humans off-Earth will have three vital consequences. First, it will make human life forever unkillable, removing it from the endangered species list, where it now stands on a fragile Earth over-armed with nuclear weapons. Second, the opening of virtually unlimited new land area in space will reduce territorial pressures and therefore diminish warfare on Earth itself. Third, the small-scale space colonies, the largest some tens of thousands of people, will lead to local governments, that are simple in form, responsive to the desires of their people, and as reachable and intimate as were the New England town meetings of America's heritage" (Gerard K. O'Neill, "Foreword," in Frank White, *The Overview Effect*, Boston: Houghton Mifflin, 1987).

O'Neill later wrote on space-based solar power, "If this development comes to pass, we will find ourselves here on Earth with a clean energy source, and we will further improve our environment by saving, each year, over a billion tons of fossil fuels" (Gerard K. O'Neill, *The High Frontier*, New York: William Morrow, 1977, 162).

Gerard K. O'Neill, "The Colonization of Space," *Physics Today*, September 1974. space.nss.org/the-colonization-of-space-gerard-k-o-neill-physics-today-1974/.

O'Neill once declared, "Almost anything can be done in a ten-year period, when we set our minds to it" (*The High Frontier* interview with Gerard K. O'Neill, youtu.be/Kyt5W812hCQ).

"Environmentalists and space explorers actually share the same overarching goal—the sustainable use of the environment around us; they just differ in the location they focus on. If we look at each community through the eyes of the other, we can think of environmentalists as people who believe in the successful colonization of planet Earth, a laudable and grandiose vision of space exploration. Space explorers, on the other hand, are an ambitious set of environmentalists who would like to extend human living to the surface of other worlds. In the process of pursuing these common ambitions, both groups reflect very practical and deep connections between them" (Charles S. Cockell, *Space on Earth*, New York: Macmillan, 2007, 6).

"There are two types in this world–voyeurs and players. And who wants to be a voyeur?" (Paul Keating, Prime Minister of Australia, 1991-1996, in a speech in 1990).

"Nothing inspires people like space does" (Karen Andrews, Federal Minister for Industry, Science and Technology, at the launch of the Australian Space Agency office in Adelaide in December 2018, www.abc.net.au/news/2018-12-11/australian-space-agency-to-be-based-in-adelaide/10608202.

"'I think the challenge for people now is the same challenge astronauts face, and that's how to be resourceful when you have limited opportunities and limited options available to you,' Mr. Thomas said" (Sarah Moss, "Australian Astronaut Andy Thomas Has Some Advice For Surviving Self Isolation," *ABC News Online*, March 30, 2020, www.abc.net.au/news/2020-03-30/coronavirus-prompts-astronaut-tips-for-living-in-confined-spaces/12099534).

"Earth's next mass extinction is avoidable–if carbon dioxide emissions are dramatically curbed and we develop and deploy technologies to remove carbon dioxide from the atmosphere. But on the current trajectory, human activity threatens to make large parts of the Earth uninhabitable–a planetary tragedy of our own making" (Andrew Glickson, "While We Fixate on Coronavirus, Earth is Hurtling Towards a Catastrophe Worse than the Dinosaur Extinction," *The Conversation*, April 3, 2020, theconversation.com/while-we-fixate-on-coronavirus-earth-is-hurtling-towards-a-catastrophe-worse-than-the-dinosaur-extinction-130869).

"According to Mr. Shvets, there are only three possible outcomes. One is that central banks win; that an economic recovery allows them to withdraw their stimulus without collapsing asset prices like stocks and housing. Not much chance of that, he reckons. The second is that governments take over, pick up the slack in jobs and cooperate with each other to solve global poverty and inequality. Slim chance. The third is war. This, he argues, is the most likely and the least pleasant outcome. Let's hope this time he's wrong"

(“Is capitalism dying or just in isolation during the coronavirus pandemic?” (Ian Verrender, *ABC News Online*, April 6, 2020, www.abc.net.au/news/2020-04-06/is-capitalism-dying-or-just-in-isolation-coronavirus/12123874).

“The planet is not used to being provoked like this, and climate systems designed to give feedback over centuries or millennia prevent us—even those who may be watching closely—from fully imagining the damage done already to the planet. But when we do truly see the world we’ve made, they say, we will also find a way to make it livable. For them, the alternative is simply unimaginable … and however sanguine you might be about the proposition that we have already ravaged the natural world, which we surely have, it is another thing entirely to consider the possibility that we have only provoked it, engineering first in ignorance and then in denial a climate system that will now go to war with us for many centuries, perhaps until it destroys us. That is what Wallace Smith Broecker, the avuncular oceanographer who coined the term ‘global warming’ means when he calls the planet an ‘angry beast.’ You could also go with ‘war machine.’ Each day we arm it more” (David Wallace-Wells, “The Uninhabitable Earth,” *New York Magazine*, July 9, 2017, nymag.com/daily/intelligencer/2017/07/climate-change-earth-too-hot-for-humans.html).

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Editors’ Notes: The global impact of the COVID-19. virus epidemic has accelerated attention to the fact that biological viruses are one of many phenomena for which national borders are irrelevant. Both Frank White and Kim Peart have been making that point in different ways for decades. Here we have them merging their thinking. We remind readers here that Policy Scientist Yehezkel Dror has been prescribing policies focusing on humanity for decades. See the Summer 2018. Special Issue of the *Journal of Space Philosophy* dedicated to the legacy of Yehezkel Dror. ***Bob Krone and Gordon Arthur*****.**

Space Education for Human Communities Living on Mars

By Barry Elsey and Amina Omarova

Preface

This is a follow-up essay to our "An Imagined Order" essay in the Summer 2019 issue of the *Journal of Space Philosophy* (Vol. 8, No. 2). That essay offered a generic approach to Space human communities. This one focuses on humans planning social societies on Mars.

It should be noted that the discourse that follows is based upon what might generally be recognised as Western thought and values. It is certainly not beyond being contested by alternative perspectives. However, the thought-lines of the authors start from a well-known source of cultural influence, notably social theories with their perspectives on the human condition. We are very aware that life on Mars might well present an entirely new paradigm of existence, yet to be discovered through lived experience.

It is an enormous topic for creative and imaginative minds, not least because at present there are no human settlements on Mars. The research-based evidence of lived experience is limited to space stations and long-stay communities in remote environments on Earth (such as Antarctica). This means that we must depend on the powers of imagination and interpretation, both our own, from science-fiction, and from scholars who have thought about these things. We must draw upon whatever sources we can discover to make sense of a big topic that is yet to happen. A good way to approach the topic is to regard our thinking and writing as a contribution to the ontology and existential realities of living on Mars, the very stuff of Space Philosophy and the vision of the Kepler Space Institute (KSI).

Some immediate questions spring to mind. What would it be like living on Mars? How would people live together? What kind of social order is likely to take shape? Specifically, what kind of governance and legal framework is desirable to live in such a remote and alien environment? How would ordinary civilian life be experienced and self-managed in a personal and community setting? And what role should Space Education play in integrating people into what comprises the social order, that is, the functional competencies of economic and military activity, the roles and responsibilities of citizenship, the cultural norms of community life and the cultivation of personal identity and the inner-directed self?

These and other questions drive the learning agenda of the program. Consider it a novel learning journey to be enjoyed as an adult education of the imagination.

Introduction

At the outset of this learning program, two important points should be made. First, in keeping with the teachings of a great adult educator, the American Malcolm Knowles

(1913-1997),[1] we believe that people of mature age, usually with a wealth of lived experience and an abundance of practical knowledge, from the workplace and life generally, learn best when they can be largely self-directed. Given that our learning program is essentially an exploratory one, we can only imagine what kind of social order will be established and how people will live as individuals and with each other. It might be helpful to acknowledge that these themes can be traced back to Aristotle and through to social theory-builders of more recent times.

Second, as program directors we can do little more than pose the questions that should concentrate your mind on the broad direction and framework of ideas that pave the way for your own exploratory learning. Our task is to construct a conceptual framework and to ask the kind of questions that stimulate your imagination and produce your own ideas. We are in no position to tell you anything. Our questions reflect concerns that others might share about the kind of social system that is likely to emerge when Space is in effect colonised by human beings, leading to the establishment of living communities. We regard Mars as the most likely planet to be settled and therefore treat it as a probable case study.

To get straight to the point, anticipating the time when human beings from Earth start to build a new frontier by establishing permanent settlements in Space, Mars in particular, we ask questions about the nature of living communities in such an extreme environment. Let us explain the basic scenario while posing the questions that form the core of the learning program for “An Imagined Order.…”

We believe it is one thing to occupy Space stations with trained experts and by extension to establish the high levels of human resource capability required to build what is likely to become a military-industrial complex (MIC) on Mars.[2] It is far more challenging to settle ordinary people and families, *civilians* rather than members of the disciplined ranks of military and corporate human resource personnel. We believe that the problems of social order, at both the community and individual psychological levels, will truly begin when families and an assortment of other civilians settle on Mars and attempt to continue lives that are drawn from Earth-bound recipe knowledge and lived experience, and they then encounter a totally different environment. Until such time, it is possible to imagine a social order commanded and controlled totally by the MIC, with no other concerns than to carry out functional tasks and to stay alive.

Our focus is upon the existential situation of whatever comprises the civilian community living in Mars settlements. They represent in tangible form the problems we have on Earth of living together in harmony and meeting all the complex psychosocial needs that go with being human. In the context of imagined (and eventually real) Space communities, our notions of a social order are immediately challenged.

[1] S. M. Knowles, E. F. Holton, and R. A. Swanson, *The Adult Learner* (Waltham, MA: Butterworth-Heinemann, 1998).
[2] P. Johnson, *Eisenhower: A Life* (New York: Viking, 2014).

In such an extreme environment, everyday life is bound to be governed by the functional prerequisites of survival and adaptation,[3] and it is likely to be dominated by what J. K. Galbraith called a governing techno-structure. A complex interrelationship of technical systems must be designed to sustain the life support system of systems that underpin a living community. In such a context, people living in Space communities would probably be constantly aware of the life-sustaining properties of technical systems, and largely controlled by them through the governing structures and processes they impose on human life. It is probably an understatement to describe the system of systems that support life in Space as complex, as the uncertainties of being in an alien environment would be a constant reminder of the fragility of life. Into this scenario we insert the *social* aspect of technical systems that support entire living communities in Space.

Our simple point is that in such a whole Space community, at least initially more like a total institution, people must live with and adapt to an extreme way of life. Will it be possible to remain human and to retain something of the ordinariness of everyday life? Will it be possible for a civil society to emerge to balance the domination of the MIC by forming democratic government under a civil legal framework? Will it be possible to uphold human values that have a moral and sustainable basis? Will it be possible to maintain a personal identity, developed through life-on-Earth experiences, in an extreme environment governed and controlled by advanced and complex technical systems?

Maybe the questions are hopelessly naïve, for whenever one reads science fiction, the social order is usually characterised as authoritarian, robotic and dystopian, far from individualism and the liberal humanism we often associate with civil society. We do not have answers, but we believe the questions about the social aspect of a complex sociotechnical system in Space communities are important ones to think about and explore through the imagination.

We are encouraging you not only to explore a feasible design for living community in Space, but also to devise an ideal-type construction that can inspire others to follow your mind steps. This is the stuff of a grand narrative that engages others in a long conversation. We believe that KSI is a visionary pioneer, which is made more powerful through the contributions of those that follow its learning programs. Further, we treat the early iterations of the learning program as a work in progress. This is in expectation that adult learners like you are bound to make valuable contribution through your own insights and interpretation to what is truly an exploration of ideas at the frontier of what is known.

You may ask why we have adopted such an open-ended and non-directive approach. One good reason is that an important feature of research is that a glimmer of an idea is often the starting point for the long learning journey. It simply grows in the mind and becomes a building block for patient desk and field research, combined with inner-directed curiosity and the desire to create knowledge. Your engagement with this program may generate the spark for your own research topic in due course. Meanwhile, enjoy the

[3] T. Campbell, *Seven Theories of Human Society* (New York: Oxford University Press, 1981), referring to the work of T. Parsons. Campbell gives an extended commentary on the contribution to social theory of Aristotle, A. Smith, T. Parsons, M. Weber and A. Schultz.

learning process of using your curiosity and imagination for creative thinking and patient research.

The notes that follow are written from a lay perspective. We are genuinely curious about the social aspects of living in Space, but not very technically informed. These general musings are intended to get you started thinking about two big philosophical questions. First, *what kind of moral and sustainable living community is possible as a long-term, ordered and established society in the alien environment of Space?* Second, *how can the leading ideas of Space education play an important role in ensuring that humans can adapt through an educational and learning system designed to enable community living in an extreme environmental context?*

We provide no off-the-shelf answers, but instead we challenge you to think, write and produce an imaginative blueprint for understanding and practical action, to use an old image. Our questions are big, difficult to answer and undoubtedly challenging to an inquiring mind. Our leaning is toward the *social* aspect of living communities and *psychological* existence in a completely different environment most of us will not have experienced before.

To focus your thoughts, we have produced a simple framework. First, we invite you to consider what rules for living should underpin any kind of society that permits long-term human survival. KSI emphasises the need for a moral order and a social structure that is sustainable. How should these worthy principles be converted into everyday values and norms of behaviour that any living community should follow? Second, we go further to ask how it is possible to live at the individual, inner-psychological level, in enclosed proximity and essential collaboration with others in a strange physical environment with a huge emphasis on survival and disciplined group behaviour. Almost certainly, such a social order is bound to challenge our notions of personal autonomy and freedom. We elaborate further on these thought-lines.

Thinking About Social Systems and Individual Needs

First, it is clear that for any human community to exist in Space, we must design an integrated social and technical system that is fit for purpose and that can not only survive in an alien environment, but also function as a complete society on a long-term basis.

We invite you to write your ideas about how this should be constructed and maintained. We encourage you to be imaginative and bold in your thinking, while keeping close to and informed by those who have written on the subject, whether in the realm of science-fiction or in scholarly discourse.

Our thinking, like most others, is influenced by what we know and understand about human society, usually drawing on what we have read and our lived experiences. In that way, we make simple assumptions about the general nature of society. We do this first by focusing attention on structure and function, such as the economy (the production and exchange of goods and services), polity (governance and the making of decisions that affects everyone), social order (an underpinning system of law, normative rules and values for living communities, preferably on some basis of democratic consensus), social culture (for social cohesion and integration, maintaining the continuities of everyday life, the special roles of family and kin, beliefs and religious practices, education, leisure and so on). For those familiar with social theory the model above is known as structural-functionalism,[4] with more elaboration to follow later.

Our core assumption is that something like what we know as society will be transferred to Space, and a new habitat formed on a similar basis, at least at the beginning of settlement on Mars. What will happen next is for us all to wonder about. Indeed, if we are to honour a grand narrative and imagined order, it is quite possible that the construction of society in Space will be of a very different kind. That is for you to imagine.

It is a big ask, as the ideal-type model must be more than a specialised space station. The community will be characterised as a highly skilled workforce dedicated to scheduled tasks as a disciplined team for set periods of time. Any living community would need such a technically competent workforce to maintain the physical system. A whole society, however, is more than that. Somehow, all that we know about living communities on Earth must be transported and relocated into the environment of Space and expected to continue as a whole society on Mars.

As many know from lived experience, human society is a messy social construction seemingly given to dysfunction and discord rather than acting as a smoothly working social system. We may dream of a cohesive and integrated society based on consensus, but we know the realities of social division and conflict. These typically arise through inequities and other divisions by economic class, cultural identity (such as race, gender, religion) and differences in access and possession of political power to change the course of events and to make things happen. Moreover, we all know that human beings come in many different psychological types and dispositions, which can mess with the best-laid plans. Can they be overcome in a social system that by necessity must live together in harmony or else disintegrate and be destroyed? We briefly return to this theme shortly.

Second, we focus on individual human needs and how they fit in with a social system that must be designed to survive in an alien environment. The Australian social researcher Hugh Mackay wrote a book entitled *What Makes Us Tick*?[5] which neatly identifies some core psychological drivers that make us what we are. There is a need for love and affection, to have a sense of place and belonging, to connect with others and be taken seriously, to have something to believe in and live for, to improve and achieve and so on. These are the essential emotional experiences of being human, and they cannot be ignored in favour of a cognitive model of humankind. Again, the thinking above belongs to another kind of social theory, usually known as social action and phenomenology, also to be explained later.

What this implies is that in addition to emphasising the social aspect of complex technical systems, and by so doing drawing on classical, macro-level theories of social systems, we pay equal attention to what is called phenomenology as a perspective on human

[4] Campbell, *Seven Theories of Human Society*, referring to the work of T. Parsons.
[5] H. Mackay, *What Makes Us Tick?* (Sydney: Hachette Australia, 2010).

behaviour. We do this because wherever human beings find themselves, including Mars, they remain individuals who constantly perceive, experience, interpret and strive to make sense of the social world they share with others. It is difficult enough living with others in Earth-bound communities, but it is likely to be more challenging fitting in to the social order of life on Mars. At least we may ask what it would be like as an individual living in such an extreme physical environment, dealing with the regimes of total and everyday systems designed to manage safety and security, being a member of whatever form community takes and just being oneself.

The KSI assumption is that whenever the dream of permanent human settlement becomes reality, human beings will be able to transfer the complete package of individual wants and needs to community living in Space. By necessity, for the sake of survival, there may well be a collective normative requirement for an extraordinary form of individual self-discipline. It is to be imagined how much the norms of social order will intrude on personal freedom. This is another open question.

What is clear is that whatever design emerges for living communities in the context of Space, it will be a complex and adaptive social system, comprising structures and functions that is likely to be more omnipresent than we know through lived experience and call human society. Moreover, because of the special adaptive behaviour requirements (an elaborate kind of health and safety mindset), it is necessary to devise ways and means of accommodating our individual psyche, the complex bundle of moving parts we like to call wants and needs that drive behaviour and give us individual identity. How can they be met in an environment far away from Earth and with no relationship with Nature to provide existential comfort?

As an important starting point for considering the inner life of living in Space, without doubt NASA and other national space exploration agencies have examined in detail the psychological effects of being on space stations and all other extreme environments to test and appraise the limits of human endurance. The NASA website gives access to such studies, which are available to the general public.

Taking social system and individual human needs together, any living community in Space must attend to how things would function in human terms. It is one thing to achieve technical mastery of Space and quite another to create and maintain living communities in a context where everything that sustains human life is transported and embedded as a continuous life support system. While that feat of technical mastery is being achieved, and maintained, ordinary life should carry on, the countless everyday interactions and social relations that hold together, like a seamless web, our experience of living community. We invite you to explore these open-ended ideas and give us your thinking. There are no right and wrong answers, but your ideas should pass the common-sense test of being plausible to reasoning minds.

Introducing Some Key Concepts That Focus Attention on the Existential Realities of Living on Mars

Behind the ideas that have so far comprised an overview of the social aspects of living on Mars, in some kind of community setting, it is useful briefly to allude to important concepts that will help you to think about and design your own ideal-type model of a social order. This entails some brief definitions and descriptions with key references should you decide to explore further and deeper.

An *ideal-type concept* refers to a hypothetical construct in which the prominent features of a social group or organisation are used to highlight a pure or ideal form, usually to illustrate an abstract generalisation. In the context of this learning program, the imaginative design of a social order for Mars is likely to be an idealised model. In practical reality, it might be different, possibly because actual life on Mars might determine a different shape and form from the idealised version.

In the context of this learning program, you are encouraged to think and design a social order for living on Mars in ideal-type terms.

Social systems with special reference to the structural-functionalist model: the British economist and philosopher Adam Smith (1723-1790) was a leading thinker in depicting society as a natural mechanism that functions purposefully to survive and adapt through economic activity and the sharing of core values that underpin a moral order to maintain continuity and foster change. The comparison with a natural organism is obvious, with the addition that human beings are naturally drawn consciously to consider their actions and the social constructions that follow in moral terms.

Two centuries later the American sociologist Talcott Parsons (1902-1979) developed a complete ideal-type structural-functionalist model of society, primarily to explain the nature of social order in which people choose to make mainstream values and norms work by their own volition. Years later his general theory was heavily criticised and largely discarded, mainly on the grounds it was deterministic and outer-directed, ignoring the myriad ways people make society work through their own subjective interpretations of reality (more later).

In the context of this learning program, the idea of functional prerequisites and the AGIL model as developed by Parsons allows us to understand the workings of the MIC and the dominance of the technostructure on Mars.

The AGIL model in simple form depicts society as having to perform four functional prerequisites as the basis of survival and adaptation:

A: *adaptation*, in which the social system produces goods and services (economic activity) within an environment. Defence systems might be considered another means of social survival when political rivals clash.

G: *goal attainment*, in which the social system mobilises its human resources, tools of technology and other resources to achieve outcomes. This is the soft side of economic activity through change management strategy and practice.

I: *integration*, in which concerted effort is made to ensure the various parts of the social system work together in support of both hard and soft parts of the economy, such as the institutional role of education in knowledge and skill transfer, socialisation into the cultural values and norms and selection according to ability and motivation. Organised religion might be considered as another means of cultural transmission. The rule of law would certainly count.

L: *latency* refers to the cultural and psychological means the social system uses to uphold and maintain the ways things are organised and managed by fostering a collective commitment to the values and goals that hold things together. This ascribes an important role and function to the sociocultural aspect of human communities.

The obvious point to make is that in all probability, whatever settlement takes shape and form (structure) on Mars, the functional activities will be predominantly about economic production, typically by extractive industries mining for required natural resources. Moreover, the military will be stationed on Mars to protect the mining industry as well as for other strategic purposes. In addition to necessary attention to ensure the economic system works effectively, there is an equal functional imperative to succeed in the complex process of survival and adaptation to a challenging external environment.

It is important to note that the holistic theory (and the ideal-type model) of a social system and its natural organism allusion was a dominant mode of sociological discourse in the United States and elsewhere until the 1960s, but it fell out of the limelight thereafter. But for our purpose, it still holds up as a plausible way of approaching how to approach the building of the foundations for a functioning settlement on Mars.

Military-Industrial Complex

In his farewell address, President Dwight D. Eisenhower expressed his concerns at the economic cost of the arms race, itself a consequence of the cold war, which was at a bitter stage, and the threat it posed to liberal democracy and governance. In a much-quoted warning, he stated:

> In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist. We must never let the weight of this combination endanger our liberties or democratic processes.[6]

Eisenhower was not thinking of human life on Mars, but we regard his statement as a call to awareness of the power of the MIC and the need to consider the nature of social order. For those of us conditioned by the values of liberal democracy, Eisenhower's words have a powerful impact. Maybe there is no room for an American liberal democracy and other features of what Europeans would recognise as social democracy on Mars. We cannot simply assume that living community on Mars will be a simple replica of what is known and understood on Earth.

In our times, other models of governance exist, most notably than that of China, which is emerging as a superpower. As one journalist noted, China is "an authoritarian,

[6] Eisenhower's farewell address, broadcast on January 17, 1961.

paternalistic system, reinforced by mass surveillance, that ostensibly guarantees the well-being and safety of citizens in return for their political acquiescence and public silence."[7]

Without passing judgement on the relative effectiveness or political and cultural history of an alternative model of governance, we can see that there is a clear connection to what might become the ruling order of the MIC on Mars. As indicated earlier, life on Mars is entirely dependent on technological systems that work effectively to keep the community alive and able to function. The governance of a dominant technostructure would provide the functional fit with the entire system of systems with human compliance a prerequisite for survival and adaptation. This model is like the space communities of science-fiction literature and a stark warning of the dangers to social order identified by Eisenhower.

The question that arises is whether the nature of governance is of importance in the context of the special conditions that apply to Mars. It is a matter of political choice and beliefs about what kind of social order is best suited to the needs of humankind. This accords with the values and vision of KSI, and it is therefore appropriate to develop it further. This is done by paying attention to the idea of civil society and related social theories that provide an alternative perspective in the main body of the text.

Civil Society

The idea that society is not only a functional and utilitarian system, designed to ensure survival, continuity and adaptation, but also a moral and ethical one owes much to the writings of Aristotle, notably through the construct of civic and political community (what he called *polis*) in the context of a city-state. The idea of citizenship also stems from the writings of Aristotle. A civil society is essentially an ideal-type model of government and law, in which the virtues of moral goodness and excellence in human behaviour are considered universal values to be aspired to and upheld by all citizens as a matter of duty. It has been a powerful and lasting ideal underpinning liberal democracies.

Aristotle's idea of a civil society was an elitist one, in which the high-born and the powerful economic and military interests within the city state became the leaders and decision-makers. While being a system governed by a constitution and rule of law, it is hardly a democratic model, as defined eloquently by Abraham Lincoln centuries later. In fact, it could easily emerge as the main model of the social order on Mars, with the dominance of the professional technical class (as modern day, elite aristocrats?) with their deep knowledge and skills of designing and managing the complex systems that make life possible on Mars. In effect, the MIC could be the rule of law and governance on Mars.

It follows that the idea of citizenship is a narrow one, more on the side of the technical class than an open-ended, cosmopolitan and predominantly civilian ideal, of which more shortly.

A modern vision of a civil society is different with more emphasis on *social capital* as the glue that holds society together.[8] In her lecture series in 1995, Eva Cox, the Australian social theorist, advanced an argument for what she termed *A Truly Civil Society*, drawing

[7] S. Tisdall, "China—Boxing Clever," *Guardian Weekly*, October 25, 2019, 14.
[8] E. Cox, *A Truly Civil Society* (Sydney: ABC Books, 1995).

on ideas and social values that belong to a long tradition of liberal-humanism. Cox promotes the idea that a civil society is a more developed social construct than elite rule by powerful minorities. Instead, she stresses the importance of community-level social integration based on the values and practices of mutual trust, reciprocity, collaboration and voluntary action, which together amount to social capital to complement the other types of financial, physical and human resources. This represents a grassroots or bottom-up perspective of the community, the city-state or, in the context of Mars, the purpose-built human settlement.

For Cox, the ways and means of a civil society is a natural form of democratic participation within a community that too easily fragments and that becomes dominated by powerful elites (what we might now call the political and corporate class). The writings of Cox and others like her belong to a romantic tradition in which great store is set on people power emerging from communities characterised by close-knit social relations and broadly shared norms and values. They provide an alternative vision of a social order that is close to an ideal-type of a civil society. They correspond to the KSI vision and values too.

The Idea of Citizenship

To some extent, the idea of citizenship overlaps civil society, as briefly explained above. With so many constructs in social theory, there is a tendency to create ideal-types, with more than a hint of romantic idealism. A modern version relies far less on Aristotle's idea of an elite of the great and good self-selecting as leaders of thought and action on behalf of the city-state. It has increasingly become, since the French Revolution, a comprehensive ideal for political action in which empowered groups based on cultural, gender, racial and other identities mobilise in pursuit of an agenda for change. Citizenship is regarded as a universal right and a claim to a natural stake in the political order. At one end of a continuum of the citizenship ideal are narrow and sectional interests asserting a wide range of rights to an even loftier vision of cosmopolitan citizenship, which would presumably be valid on Mars as much as across the nation-state divides on Earth. We will develop this point later.[9]

Social Action and Phenomenology

In the final overview of social theory concepts and ideal-type models, there is an alternative to the dominance of social systems. Several schools of thought under the broad heading of social action theory represent a different way of understanding human behaviour in social relationships in what is commonly called society.

Using the structural-functionalist perspective as an illustration, the model implies that human beings and group behaviour is largely outer-directed. The idea of society is not much more than a deterministic system of commands and controls that we are socialised from birth into compliance with to meet the functional requirements of society (the AGIL model). Political economy is another way of ensuring that the social order is predominantly organised around productivity, as a means of survival and adaptation. Organised education, religion, media and other systems of cultural transmission all play their part in ensuring the system is fit for purpose by directing and controlling our everyday

[9] Campbell, *Seven Theories of Human Society*.

lives. We learn to become model citizens and we are worked on ceaselessly to contribute to achieve functional fit between all the moving parts of society through our social relationships and purposeful interactions, underpinned by shared norms and values.[10] The social order is comparable to natural organisms that have inhabited Earth for millennia. Humans, as social group animals, are relatively late arrivals, but like other living species, we have a remarkable capacity to survive and adapt to all kinds of environments. As an ideal-type model, it is almost perfectly suited to creating a social order on Mars.

Such a deterministic, outer-directed model is comparable with so much science-fiction writing, in which human behaviour, notably the way humans interact through a very top-down social order, is for some a militaristic, robot-like and dystopian horror story. Something is not right about the nature of social relationships in both social theory-building and sci-fi literature. The model has little to contribute to understanding the human need for inner direction and personal autonomy, giving a sense of freedom to choose a path in life. Hence, we turn to social action theories, particularly phenomenology, as an alternative way of understanding society through individual social actions.

The starting point for understanding the nature of social being as individual action is the idea that relating and interacting with others is a continuous activity throughout life. It is an inner-directed process engaging conscious awareness of others communicated through tacit knowing, such as spoken language, signs and symbols, and in the recognition of norms and values that influence social relationships.[11] The process involves perception and subjective interpretation of what is going on, and it becomes a pattern of social behaviour that enables the individual to make sense and meaning of the myriad social worlds that comprise interactions with others. It is a constant activity, and it involves checking with and getting feedback from others in order to stay in tune. There is strong motivation to gain acceptance and recognition from others in various groups. If things work well, there is a balance between inner direction, which provides personal autonomy, and the need to comply with the outer direction through the norms and values within wider society.

In a nutshell, the model of society that emerges is one built from the everyday actions of millions. It is grounded in the common-sense behaviour of members of society mediated through social relationships, as all involved have to make their way in the world through meaningful interactions recognised by others. Essentially, phenomenology is based on the idea that lived experience, perception and the subjective interpretation of what is commonly called social reality are the building blocks of society. This understanding of how society is built and maintained is a far cry from the top-down determinism of classic social systems models, and it allows scope for individual actions that reflect our personality and other differences, as well as for consensual behaviour learned through the norms and values shared by all members of groups, large and small, mainstream and minority.

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[10] J. Hassard, *Sociology and Organization Theory*, Cambridge Studies in Management (Cambridge: Cambridge University Press, 1993). This is a commentary on structural-functionalist theory and the contribution of T. Parsons.

[11] Campbell, *Seven Theories of Human Society*, referring to the work of A. Schultz.

The capacity to define the situation for oneself brings into focus what it means to have personal freedom, which is a valued commodity in most lives. Immediately it may be assumed that life on Mars will be governed right down to the micro level by a deterministic system of systems, mainly in the interest of safety and security. What would it mean for that sense of personal autonomy we take for granted in everyday life on Earth? This is a deep philosophical question, essentially about the nature of being, that is, what does it mean to be human on Mars?

A useful approach to the idea of personal freedom is from the social philosopher Isaiah Berlin, who suggested two kinds: negative and positive freedom.[12] Negative freedom is that psychological inner space, which is an exclusively private domain in the mind and is accountable to nobody else. Without such a private mental space the individual feels cramped and unable to participate fully in the social world outside the inner-directed self with a strong form of individualism.[13]

Positive freedom is a variant of the idea of an active form of cosmopolitan citizenship in which the individual is fully engaged in the political discourse of community affairs using knowledge and experience, personal social capital, rational thought and action intended to address problems and seek solutions. At its best, it is democracy at work with the battle of ideas on an equal basis without fear of forces that might easily oppress and retain power. There is no need to underscore the idealism reflected in both kinds of freedom, but in the context of life on Mars, it might become a strong, alternative ideal-type model to follow.

Recap: The Ontology and Existential Reality of Living on Mars

We have deliberately introduced, albeit in a brief and condensed way, some leading ideas that focus one way or another on social theories and ideal-type models that provide a philosophical aspect to the prospect of living on Mars. Almost certainly, when humans do create settlements on Mars, Earth-bound ideas about the kind of social order to accompany the activities of the MIC will predominate. Even so, it could be that the nature of existence on Mars is so profoundly different as a lived experience that the idea of being human will change. We can only guess, but Space Philosophy at this juncture is just that: a reaching out of creative thinking and imagination. Moreover, we have taken up the vision and values of KSI and converted them into leading questions and thought-provoking arguments supported by concepts, models and theories drawn from classical sociology.

Before continuing with the essay, it is useful to remind ourselves of the essence of these social constructs. The emerging argument is that the life support sociotechnical, system of systems designed for living on Mars will be an astonishing feat of technical mastery. The MIC will dominate what humans do on Mars, and with it will go a social system of governance of such detailed, outer control over their lives that the nature of being will be closer to that of a robot. It is a stark and unattractive scenario, especially if one holds beliefs and values about human rights to the inner-directed self, usually expressed as

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[12] See P. Watson, *A Terrible Beauty: A History of the People & Ideas That Shaped the Modern Mind* (London: Weidenfeld & Nicholson, 2000), which contains valuable insights into the ideas of J. K. Galbraith, I. Berlin, D. Riesman and others who helped in the writing of this essay.

[13] Watson, *A Terrible Beauty*, referring to the wok of D. Riesman.

individual autonomy and personal freedom that come from the ideals of liberal humanism that can be traced back to the Enlightenment.

It is possible, of course, that the MIC may not impose its form of top-down governance, but the determinism built into social and technical systems makes that prospect unlikely. If humans are to have a social and personal life that resembles what is a common lived experience on Earth communities, then it is necessary to create a civil society with all the trappings of democratic participation in the creation and maintenance of a social order fit for humans, not just fit for instrumental and rational purposes.

Expressed in simple terms, life on Mars is either to become a controlled and commanded social order characterised by deterministic systems or another venture in what it is like to be human, accompanied by all the kinds of personal freedom noted earlier, in a totally different environment, like nothing on Earth.

We continue with the essay, which eventually leads to questions about the design, role and purpose of Space Education.

Thinking Further About Human Society as Living Community in Space

There is a long history of imaginative literary and science fiction writing about human beings living in the alien environment of Space, with at least one trilogy focused on Mars.[14] We can all marvel at the scientific and technical mastery of spaceship travel and exploration, together with the disciplined, team-based work of those living in space stations. We are reaching the stage of human accomplishment at which it now seems feasible to consider the practical possibility of non-specialist living communities, ideally in sustainable and ordered permanent settlement in Space, notably Mars. That is certainly the visionary assumption of KSI, driven by a passion to ensure that whatever form human society takes, it is founded on shared values and core rules for living all can voluntarily embrace.

Undoubtedly, there is a long road ahead in perfecting the complex and technical aspects of building a sustainable infrastructure as a platform for human life for whole communities in Space. However, that is not the primary focus of this learning program. Instead attention is concentrated on the social aspects of a complex technical system to support human life. We need to think about transferring what is presently known and understood about living communities on Earth and creating sustainable human settlement in the alien environment of Space. This process may well entail revisiting the designs for living communities to assist their capability for adaptation for living in Space. How much change to what we know, value and believe about living communities will be required? While the technical mastery of that process is achieved, big questions arise about how such human communities should function; what we commonly refer to as a whole society. More specifically, we need to pay extra attention to the role of education as a system, designed to produce a quality learning environment from early childhood through to continuing and lifelong provision into old age. More about these matters follows later.

[14] K. S. Robinson *Red Mars* (New York: Spectra, 1992); K. S. Robinson, *Green Mars* (New York: Bantam Books, 1993); K. S. Robinson, *Blue Mars* (New York: Random House, 1996).

As a general observation, the fictional social construction of human communities in Space is hardly a recommendation for the kind of society in which most people would want to live. As seen on TV and movie screens and read in science fiction, human society is typically run as authoritarian, military-style dictatorships, modelled on a dystopian society or like an imperial or feudal colony. Such images are most unattractive, and nothing like the liberal social democracies many have lived in. Is there anything of value to be learned from sci-fi literature that would help us to comprehend how human should live, ideally as free-thinking citizens carrying forward what might be called the best of civilisation on Earth? This is a different kind of new frontier thinking, and imaginative thinking from literature sources may not be much help. This is for you to decide, based on what you have read and what has inspired you.

There are also real-life examples of specialist and continuous communities, typically managed as impressive team-based organisations, to be found in the harsh environment of Antarctica and in working space stations. By they are just that, a community of highly trained and disciplined workers undertaking specialist tasks with a fixed-term contract to perform set roles and responsibilities. They are extraordinary communities, and certainly not the everyday ones we are all familiar with wherever we live on Earth.

Before engaging in further leaps of human imagination of an idealised society, we should pause to contemplate the reality of the living community on Earth. Even a cursory reading of Yuval Noah Harari's latest book, *21 Lessons for the 21st Century*[15] alerts us to the manifold challenges of human societies. The book explores the big themes of technology disruption, environmental degradation and extreme capitalism forcing human adaptation to constant and threatening changes that few are adequately prepared to embrace. The mass uncertainty that follows impacts everyone, notably in securing the core essentials of everyday life, such as having a decent work future and a healthy life balance. Moreover, growing disillusionment with the nature of the political process and governance has disrupted faith in finding democratic solutions to the quest for social fairness and justice. Political populism fosters the myopia of inward-looking nationalism, and the spread of global terrorism creates an unease that these and other issues are barely manageable. As we are propelled forward, we collectively lack confidence in long-standing traditions and institutions to meet the challenge of change. This dark and dismal scenario, the future the author claims we are in now, is hardly a secure foundation for contemplating, planning and implementing a bold design for establishing living communities in the alien environment of Space. At least the writings of Harari and others on the threats to societies as we know them warn against being naïve and simplistic as the vision of inhabiting Mars becomes a workable reality.

At the same time, the vision of KSI is of a future that may be both technically and socially realisable. The vision is one of hope and passionate belief that human beings have the capability to create and maintain new societies, even in the alien environment of Space. Maybe the extreme nature of the environment is the kind of collective challenge that humans need to construct an ideal-type society.

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[15] Y. N. Harari, *21 Lessons for the 21st Century* (London: Jonathan Cape, 2018).

Assignment 1: Your First Thinking and Writing Task

At this juncture, we pause from our musings and pay attention to yours. We invite you to trawl selectively through the *fictional* literature (commonly called sci-fi) on Outer Space exploration and human settlement and identify examples you consider worthy of recognition for the quality of imagination and the elegance of writing. Travel back as far as you like, when science-fiction writing made an appearance and took hold of the popular imagination. Bring your reading into the present and taking all that you have read (and seen), describe how human settlement in Outer Space, what we call society and living community, is imagined and created. What kind of society is depicted? Is it like what we know on Earth or something else? Could ordinary people live in such a society, without becoming like robots and having no individual identity? Explain what you have found, and then compare with the vision of KSI. Can we seriously learn from fictional imagination? Where is reality in the fictional literature?

Write between 1,000 and 2,000 words summarising your findings and analysis. Ensure that you have cited the sources you drew upon to create your own interpretation. Please submit your assignment as a portfolio at the conclusion of the program. Regard everything you write as a work in progress.

If possible, share your thoughts as they take shape through your reading and thinking with fellow students. Remember, we are all on a journey of discovery

Assignment 2: Investigating the Serious Scholarly Literature on Human Settlement in Outer Space.

This is a challenging academic task. You need to identify the *scholarly*, research-based and philosophical literature that has gone beyond science fiction to examine how humans live in alien environments. For instance, a very readable 2019 publication accompanying a much-praised BBC series,[16] explores the solar system and has a chapter on Mars, the sister to Earth. Another useful starting point might be the communities from many nations that live for long periods in Antarctica. They must have deep and extensive experience of how such isolated communities live with each other. Going a step further, what is known about human life on space stations? What holds these specialised communities together? What can be learned from such actual experience and incorporated into your ideal-type model for living community in Outer Space? Has anyone, in the KSI network and beyond written about the possibilities of human settlement in Space? How plausible are their thinking and designs for living?

Our advice in starting to explore this aspect of living communities in Space is to search for authors who have paved the way with their own ideas and have taken the long journey into public scrutiny through publication. The KSI in-house *Journal of Space Philosophy* is an excellent starting point, for it expresses the core vision and values and seeks to apply them in meaningful ways.[17] One author to take special note of is Yehezkel Dror, for he has left a trail of leading ideas that might well provide a foundation for your own

[16] A. Cohen and B. Cox, *The Planets* (London: Collins, 2019).

[17] Krone, Bob, Editor-in-Chief, *Journal of Space Philosophy*, keplerspaceinstitute.com/jsp/.

explorations. There are bound to be others reaching out with their ideas that might ignite your own.

Write between 1,000 and 2,000 words summarising your findings and analysis. Ensure that you have cited the sources you drew upon to create your own interpretation. Please submit your assignment as a portfolio at the conclusion of the program. Regard everything you write as a work in progress.

Again, if possible, share your thoughts as they take shape through your reading and thinking with fellow students. Remember, we are all on a journey of discovery

Thinking about Space Education

Thinking about the social aspects of living communities in Space leads to the special focus of this learning program, which is with leading ideas about Space Education. If communities are to live in Space, Mars as a starting point, there is surely an imperative need for a system of education and training to transfer knowledge and to develop special competencies designed to make everyday living possible. Moreover, as living on Mars will be regarded as a new learning experience, it is a challenge to design an education system that is a best practice model for human development. This is where Quality Space Education makes an entrance into our thinking.

As contextual background, Space Education comprises several types of learning activity. First, there is a growing body of general knowledge for public education promoted through the media and specialised agencies, no doubt responsible for the popularity of all aspects of Space exploration and for the sheer adventure and awe. Second, educational bodies of all kinds and stages have devoted varied interest in and attention to Space Education, which must compete with mainstream learning programs. Third, specialised agencies such as NASA are responsible for the training and development of Space industry personnel with links to universities and research institutions to provide knowledge and educational support. Even more specialised are those agencies that train and prepare astronauts and high-skills workers on space stations. Probably several training programs are already preparing personnel within the MIC to create settlements on Mars. It is the latter group and the civilians who may follow that concentrate our attention on Space Education, that is, those who are going to live on Mars.

Before attending to Space Education as a concept, it is useful to be reminded of the key feature of formal education as an organised system. This usually means a whole society system, typically directed and controlled by government and often incorporating private sector institutions, in democratic societies for sure. Use your imagination to create an educational system designed for living communities on Mars. It should start at birth, continue as a lifelong learning process and be available to all, regardless of social position in an imagined Mars community. In other words, the design of the education system should be on inclusive principles, for civilians as much as the members and families of the MIC.

In the most general terms, the purpose of an educational system is to transfer knowledge and learned culture from one generation to the next and between all strata and groups of society (social classes, racial and ethnic groups and so forth). The intention is that such a system of cultural transmission serves to integrate all kinds of people and subcultures into the recognisable form of a cohesive whole society unified under the banner of a nation state (remember the AGIL model of structural-functionalist social systems theory). All that the society knows, the accumulated knowledge and skills that enable it to function in economic, political and many other ways, must be passed on and learned to maintain continuity and to adapt to a changing world. This process is not just about transferring selected and valued knowledge and skills, but also socialising new generations into the cultural values and normative order of society.

With increasingly complex economies with high-order knowledge and skill requirements, the educational system must also devise ways and means of selecting by ability to supply capable human resources. Selection by merit often competes with other forms of self-selection by wealth and social advantage. Expressed another way, it is well known that equal access and opportunity in educational systems, whether by social class, race or ethnic identity, does not exist, especially in poor countries and poor regions within rich countries. One safe assumption is that any living community on Mars must ensure that the competencies for survival and maintenance of a complex social-technical system are selected and developed through well-designed education and training.

Problematically, merit selection by ability is not an exact science, and it is often characterised by relative failure to identify and nurture the kinds of intelligence that schools and education generally are intended to foster. These matters truly worry educators and policy makers, hence the emergence of Quality Education to identify and address them.

The concept of Quality Education is both aspirational and inspirational. It has emerged as one of the big ideas that international bodies like to embrace and promote as a universal strategy for improving all aspects of education as a system of provision for all ages. However, it is more than strategic thinking about access and equity to educational provision and a fair system of resource allocation. The idea of Quality Education has clearly inspired educators to think about and design improved ways and means of making teaching and learning more effective, with outcomes that meet both societal and individual needs. We shall concentrate more attention on teaching and learning matters than on system improvement, as they reach to the core of our lived experience of education in our early years and beyond into adulthood and old age.

It is useful to highlight the leading ideas of Quality Education as a prompt for your own thinking. These should be linked to what Quality Education would mean in conceptual and practical terms within the special context of living communities on Mars. We continue our musings about this theme, which is at the heart of Space Education.

In the imagined context of living communities on Mars, both survival and adaptation are imperatives to ensure that all members of society learn to live in an alien environment. There is much to learn from the accumulated knowledge and skills of those who have lived on space stations and isolated communities on Earth. This kind of learning must begin at birth and continue as a lifelong process. There is a need for a system of lifelong education designed to ensure that everyone knows how to survive and possesses the skills to adapt to everyday living, quite possibly under conditions of constant threat of disaster. We might term this as basic Space Education.

The question to ask is whether educational systems on Earth are fit for purpose for such extreme conditions. In such an environment, learning must surely be concentrated on (1) functional knowledge for survival and adaptation, (2) learning to live together under very challenging social and individual psychological conditions, (3) acquiring and continuously supporting social attitudes and behaviour that pose no serious threat to the social order and (4) developing intellectual, creative and other human talents that enable individuals to experience self-actualisation, that is, being the best one is capable of being. Any education system that can perform to such a high level of expectation is what quality means. It is a tall order, and most education systems on Earth fall short. It is better to assume that there is at least room for improvement, which is why Quality Education is a useful cue to think afresh about what an ideal-type educational system should be like.

Concentrating attention not on a total system, but on the core activities of teaching and learning, whether in a traditional classroom or workplace or another setting where knowledge and skill transfer is undertaken, some leading thinkers have emerged to point the way forward. There are scores of ways and means of making teaching and learning effective, and many advocates. Those of us who have faced a group of learners, typically of mixed ability, motivation and attention span, know how difficult it is to be an effective teacher or learning facilitator, to use a fashionable term in adult learning. Our choice is limited to one educator who articulates the aspirations of Quality Education in the complex process of enabling the learning of others through a best practice approach to teaching. We refer to the work of Robert Marzano, especially his book *The New Art and Science of Teaching*.[18]

There will be countless numbers of good teachers who follow Marzano in setting goals for learners, give feedback and assist them to deal with new knowledge and new learning experiences so that they develop a conceptual grasp and a sense of ownership, actively engage with students in the learning process and maintain good working relationships, and generally inspire them to aim high through hard work and application. This requires a high level of awareness by the teacher or facilitator to ensure that learning follows a developmental pathway, as it is easy to lose momentum and to stray off track. For both learners and their helpers, it is well known that gaining new knowledge is mostly hard work, but it is often inspired by the motivation to succeed. In that sense, Marzano reminds us that the conditions and process for good teaching and learning are accessible and manageable.

At that juncture, it is important that the educational system designs an institutional framework that is based on and adequately supports the various expressions of Quality Education. Emphasis should go on teaching and learning and the variety of forms it can take in the complex process of knowledge and skill transfer. The idea of Quality Education should not be confined to what is often called the school age years, but it should begin

[18] R. J. Marzano, *The New Art and Science of Teaching* (Bloomington, IN: Solution Tree Press, 2019).

earlier and continue as a system of lifelong education. There is nothing unreasonable about a comprehensive education and training system available and accessible to all, except for gaining traction politically and economically as a universal human right.

We know of the long road ahead in establishing an ideal-type model of Quality Education on Earth; therefore, the question arises, is it any more achievable in living communities in Space and on Mars? What spirit and form would Quality Education take in such an extreme environment? These two open questions should be addressed in your third assignment.

A possible guide to your thinking comes from the writings of another American academic, Howard Gardner of the Harvard Business School. In *Five Minds for the Future*,[19] he identifies qualities of mental development that depend on a sound educational upbringing in family and home, school and community, workplaces and elsewhere throughout the lifetime journey. In that way he embraces all kinds of education and training as a lifelong process. His ideas are relevant to designing a Quality Space Education.

In summary, Gardner writes about the cognitive and affective qualities of mind development that together enable people to adapt to a changing world. The first mind for the future is the capacity to practice a *disciplined* mind, which involves the mastery of subject knowledge and knowing how to apply it as a continuous learning process. The second mind is the *synthesizing* one, meaning the competence to connect ideas and to make sense of them in inventive ways. The process involves constructing narratives, the ordering of knowledge and ideas through taxonomies and other kinds of condensed explanations, engaging with complexity where the rules of linear thought fail to work, confidence in thinking thematically and theoretically while using metaphor to convey ideas. This kind of mind is required for multidisciplinary knowledge development rather than a single subject focus. The third mind is the *creative* kind, and it forms a close link with the synthesizing one, typically expressed as the ability to think outside the box and to engage in lateral thought as much as a linear form. Such capability accords well with the knowledge-based economy and the use of AI and other advanced tools of computer technology. All three minds depend on cognitive capability and require extensive education and training throughout life.

The two other kinds of mind are more about personal qualities and the capability to communicate effectively with others through inter-personal relationships. The fourth mind is the *respectful* one and the fifth an *ethical* one. The respectful mind is necessary for living with cultural and inter-group diversity by accepting differences and making the experience a positive one, in keeping with the ideal of cosmopolitan citizenship. The ethical mind is sensitive to the needs of others, and it places self-interest lower than doing the right thing, as a good civilised person should. These qualities of mind cannot be left only to the school to socialise and develop; they are also a family and communitywide responsibility.

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[19] H. Gardner, *Five Minds for the Future* (Cambridge, MA: Harvard Business School, 2007).

In any kind of learning context, it would be hard to disagree with Gardner's *Five Minds for the Future* scenario and core argument. His ideas are very appropriate for any society that embraces change and modernity. However, in our view, his ideal-type model falls short of an important element that goes further than high-level competence, which is what Gardner advances as minds for the future. The education quality we are searching for is not as easy to locate as learning and knowledge subject matter, but it exists as a kind of spirit that should pervade the system. One line of argument we have promoted is that living on Mars could easily become closer to the life of a robot than is suited to a full-fledged human being. We have in mind understanding human behaviour, with all the complications of character, personality, attitude and other ways and means that lived experience is shaped and moulded through the various ages and stages to produce individual differences and diversity. Life on Mars could be relentlessly boring with insufficient cultural stimulus to make living interesting as well as challenging. This comes back to designing an applied teaching and learning approach and process that fosters the spirit of individualism, whether it accords with the wishes and norms of the authorities or not. This is much more than competence development, but what it is and how it should be transmitted is elusive.

What is clear is that Space Education on Mars should not be a copy of the systems that dominate education and training on Earth. The existential reality is going to be different, and that kind of unknown quality should be the foundation for Space Education rather than Earth-bound conventions.

Write between 1,000 and 2,000 words summarising your thoughts. Ensure that you have cited the sources you drew upon to create your own interpretation. Please submit your assignment as a portfolio at the conclusion of the program. Regard everything you write as a work in progress. Share your ideas with fellow students as they take shape.

Summary

We have deliberately adopted a non-technical approach to what are open questions that any lay person might ask about the possibilities of creating moral and sustainable living communities in Space, with special attention to Mars as the most likely place for human settlement. Our musings have also involved some repetition, in a natural desire to emphasise the thought lines we consider important. Sorry.

We have assumed that sometime in the future, the dream of living communities in Space becomes an everyday reality. No doubt we will marvel at the science and technical mastery that has created the dreams of science fiction writers and countless experts in a concerted multinational endeavour. KSI has rightly identified the imperative to ensure that such a bold vision is framed by principles and practices that provide a moral and sustainable social order. This must be to enhance the immense technical requirements for survival in an alien environment, but also to prevent social chaos and disintegration through conflict and division. Moral principles and sustainable values exist for a purpose, and in Space, there may be little room to deviate from a well-constructed social order.

To be more specific, your imagined order must surely address what rules for living should be made explicit and form a continuous awareness of the imperative for survival on terms and conditions that avoid destruction. This implies a social order based on consensus, but what form should it take? Is it what many of us know as liberal democracy? Should the people have some say in who governs and how they are governed, or should government take a different form?

Without ignoring such broad-ranging questions of political philosophy, we must also attend to severely practical matters. A big issue of sustainable principle would be how to manage waste. There would be scores of other sustainability-type matters to be raised and resolved. Leaping to another level, how are humans to be sustained spiritually? It is not essential to believe in God, but an absence of the comforts of nature and the wild to our spiritual lives must be considered a problem to be addressed. These and other matters underscore what we mean by an imagined social order that supports body, mind and spirit, and how things should work at all levels of human consciousness in a challenging and alien environment.

Into your blueprint, we invited you to consider the important role of education and training, with special reference to how such a system would operate in a Space community and environment. Just like our thinking about an ideal-type social order as well as an educational one, we are painfully aware of the shortcomings of systems on Earth. This prompts the question whether in creating living communities Outer Space, it is necessary to think afresh and to produce a completely different social and educational order, not a copy of the Earthly ones.

Into such a complex setting, we invite you to think about the nature of such a social and educational order and to provide your own interpretive blueprint. Freely use your creative imagination, but also connect with those who have also thought about these matters and engage in a discourse with their writings.

That is what we are asking you to do in the three linked assignments, which should give expression to your thinking and provide an annotated bibliography of the works of other authors you found useful. Consider yourselves pioneers in the KSI learning community, for others may well seek to learn from you.

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Editors' Notes: All the reality of human Space settlements remains in the future. We know it will happen. We also know that how it happens will be the critically important success variable for the future improvement and survival of humanity. Dr. Barry Elsey and Dr. Amina Omarova here give the Space community an original and complex discussion and guidance for graduate-level research, planning, and designing of future Space communities on Mars. It will be a prime research document for KSI scholars. Dr. Elsey is the Dean of KSI's Department of Space Education, with a distinguished career of Supervising doctoral degree candidates. Dr. Omarova was one of his successful candidates. ***Bob Krone and Gordon Arthur.***

Recursive Distinctioning as a Context for Thinking About Processes

By Louis H. Kauffman and Joel Isaacson

I. A Quick Introduction to Recursive Distinctioning.

Recursive Distinctioning (RD) means just what it says. A pattern of distinctions is given in a space based on a graphical structure (such as a line of print or planar lattice or given graph). Each node of the graph is occupied by a letter from some arbitrary alphabet. A specialized alphabet is given that can indicate distinctions about neighbors of a given node. The neighbors of a node are all nodes that are connected to the given node by edges in the graph. The letters in the specialized alphabet (call it SA) are used to describe the states of the letters in the given graph and at each stage in the recursion, letters in the SA are written at all nodes in the graph, describing its previous state. The recursive structure that results from the iteration of descriptions is called RD. Here is an example. We use a line graph and represent it just as a finite row of letters. The Special Alphabet is SA = {=, [,], O} where "=" means that the letters to the left and to the right are equal to the letter in the middle. Thus if we had AAA in the line then the middle A would be replaced by =. The symbol "[" means that the letter to the LEFT is different. Thus in ABB the middle letter would be replaced by [. The symbol "]" means that the letter to the right is different. And finally, the symbol "O" means that the letters both to the left and to the right are different. SA is a tiny language of elementary letter-distinctions. Here is an example of this RD in operation where we use the proverbial three dots to indicate a long string of letters in the same pattern. For example,

... AAAAAAAAAABAAAAAAAAAA ... is replaced by

... =========]O[========= ... is replaced by

... ========]OOO[======== ... is replaced by

... =======]O[=]O[======= ... .

Note that the element]O[appears and it has replicated itself in a kind of mitosis. To see this in more detail, see the output from a mathematical program written by LK that uses a blank or unmarked state instead of the = sign.[1] Elementary RD patterns are fundamental, and they will be found in many structures at all levels. There is also a cellular automaton example of this phenomenon.[2] In it, we see a replicator in *HighLife*, a modification of John Horton Conway's automaton *Life*. The *HighLife* replicator follows the same pattern as our RD replicator! We can begin to understand how the RD replicator works. This gives a foundation for understanding how the more complex *HighLife* replicator behaves in its context. Finally, an excerpt from a paper by LK about replication in biology and the role of RD illuminates this further.[3]

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[1] www.dropbox.com/s/tkkye8g99tzm0xm/RDL.pdf?dl=0.

[2] en.wikipedia.org/wiki/Highlife_(cellular_automaton).

[3] www.dropbox.com/s/zm785d20bma6tb2/KauffmanExcerpt.pdf?dl=0.

RD is the study of systems that use a symbolic alphabetic language that can describe the neighborhood of a locus (in a network) occupied by a given icon or letter or element of language. An icon representing the distinctions between the original icon and its neighbors is formed, and it replaces the original icon. This process continues recursively.

RD processes encompass a very wide class of recursive processes in this context of language, geometry, and logic. These elements are fundamental to cybernetics and they cross the boundaries between what is traditionally called first- and second-order cybernetics. This is particularly the case when the observer of the RD system is taken to be a serious aspect of that system. Then the elementary and automatic distinctions within the system are integrated with the higher order discriminations of the observer. The very simplest RD processes have dialectical properties, exhibit counting, and exhibit patterns of self-replication. Thus, one has in the first RD a microcosm of cybernetics and perhaps, a microcosm of the world.[4]

II. Variants of RD

The key point about RD as we have described it in Section I is that it is a recursive process of distinctions such that at each step in the process, new distinctions are built that represent the distinctions that were present at the previous level. This continues recursively. The particular way that the new distinctions are built in our model for RD is that a boundary is created between two nodes (locations) if these locations were different in the previous state, and no boundary is placed if they are the same. The tests for difference and sameness are local and based on contiguity of forms.

One can have a system in which local changes are made according to rules that respect local distinctions, but the local changes are not simply the placement of boundaries.

For example, consider the following system. We have strings with three types of entries: {*, <, >}. These are stars (*), left brackets (<) and right brackets (>). The basic rule is: ** => <*>. That is, two consecutive stars are replaced by a bracket around a star. The second rule is: >< => nothing. That is, two opposite brackets cancel each other. Consider what happens to a row of stars.

```
*******************
<*><*><*><*><*><*><*><*><*>*
<**><**><**><***>*
<<*>><<*>><<*>><<*>*>*
<<*><*><*><*>*>*
<<****>*>*
<<<*><*>>*>*
<<<**>>*>*
<<<<*>>>*>*
```

[4] See the Special Issue of the *Journal of Space Philosophy* (Vol. 5, No. 1; Spring 2016) devoted to RD.

The reader can have some fun seeing how any row of stars will reach a reduced form under this recursion.[5]

A clue:

<<<<*>>>*>*

<<<<1>>>1>1

<<<<1>0>0>1>1

10011

The point we wish to make is that this system is an *RD variant* in the sense that it works by local interactions that depend upon the distinctions inherent between the local forms that are in the strings of the system.

We suggest that many recursive systems in natural science and in mathematics can be seen as RD variants and that it will be fruitful to look at the world of recursions from this point of view.

Needless to say, we are particularly interested in RD variants where the rules are fundamentally simple, since we believe that nature does not make her decisions on the basis of big computations carried out to determine local actions. We believe that there are essentially no computations of this sort in the local actions of natural systems.

III. Meta Variants of RD – Recursive Description

There is another sort of RD variant that we wish to pinpoint.

Consider the following sequence of strings

1

11

21

1211

111221

312211

13112221

1113213211

…

As the reader can see, each line is a description of the previous line.

111221

[5] See homepages.math.uic.edu/~kauffman/ArithForm.pdf for more information about this system and its relationship with binary representations of numbers.

three ones, two twos, one one:

312211

where the description is reencoded (without commas!) as a string of numbers. This recursive describing works very similarly to RD.

But you will note that in making the description, we must ascend to a descriptive level that is expressed at the coding level. Something like recursive description goes on with the DNA and RNA interplay in molecular biology. In human conversation, we engage in recursive description at all levels of the linguistic interaction.

We regard recursive description as a highly significant variant of RD.

IV. Molecular Biology and Virology

In the full complexity of molecular biology, we have not only the fantastic workings of the cells, but also the diabolical workings of the virus, where a molecular object has only parasitic existence and depends for its livelihood on interaction with a cell as environment for its viral DNA. Here again we have a powerful RD variant where an entity (the virus) can engage in key-in-lock interaction with cellular membranes to use the cellular environment for its individual recursion and self production (Figures 1 and 2).

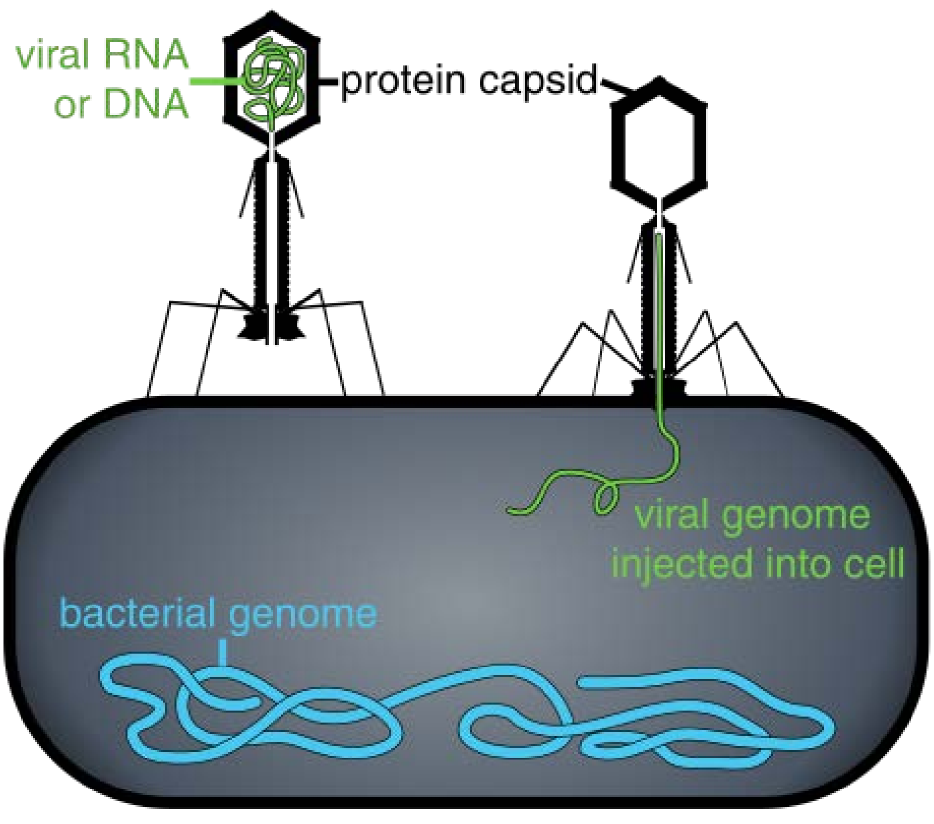

Figure 1. Schematic diagram of a virus invading a cell.

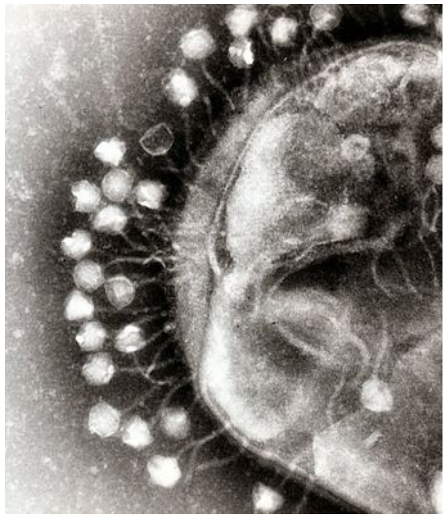

Figure 2. Illustration of a virus invading a cell.

At the level of the virus, and indeed the cells and the DNA and the RNA, we are at a key interface between classical mechanical mechanism and interaction, the quantum world and the living world. In the quantum world the no-cloning theorem forbids the duplication of quantum states. In the world of DNA. replication is the key. In the simplest world of RD, replication is the first action of the system (see the first lines of Section I herein). Mechanism and recursion arise together in the context of distinction. How do these mechanisms arise in the nexus of quanta, classica and life?

This is the central question that we can only ask and expect a cornucopia of answers.

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Editors' Notes: Dr. Joel Isaacson and Dr. Louis Kauffman have been the leading scientists for the discovery of and research in RD. Many of their publications can be found in issues of the *Journal of Space Philosophy*. Kepler Space Institute (KSI) will host the 5th Annual Recursive Distinctioning Conference, virtually, on May 9 and 10, 2020. This publication is occurring at the peak of the COVID-19 Pandemic global crisis. Readers should note the following Kauffman-Isaacson quote on page 45:

> In the full complexity of molecular biology, we have not only the fantastic workings of the cells, but also the diabolical workings of the virus, where a molecular object has only parasitic existence and depends for its livelihood on interaction with a cell as environment for its viral DNA. Here again we have a powerful RD variant where an entity (the virus) can engage in key-in-lock interaction with cellular membranes to use the cellular environment for its individual recursion and self production (Figures 1 and 2).

Also, in an April 12, 2020 email, Joel Isaacson wrote, “There is no indication that RD or its variants offer any sort of relief for COVID-19 but it might be useful to invest in RD and its variants in the context of the much broader research for [a] remedy to COVID-19.”

***Gordon Arthur and Bob Krone*.**

Thoughts on Future Space Research and Education

By Jeff Greason

As I am to begin teaching a course at Kepler this summer, I have been asked to share my thoughts on what the needs and opportunities are for space research and education; a dauntingly broad topic, but here they are.

Discussing what is desirable in space inevitably comes back to some questions of values; you cannot talk about improving things without a framework for what good is. That is a value judgement; in my case, I am interested in the well-being and opportunity for advancement by individuals—sapients—persons. At the present time, we only have humans in this category, and I am not expecting either machines or non-terrestrial life forms to become an interest we have to consider in my lifetime. Now, one cannot have human individuals without humanity; one cannot have humanity without life, one cannot have life without a habitable biosphere and an ongoing source of energy to power it, and so on.

I think we in the space movement labor under an intellectual burden that dates back to the beginning of space flight; because it was done by nation-states, for national interests, as part of large, centrally planned programs, we began to think about it, and speak about it, as if it were a designed or planned thing. That is a bit odd. Neither humans nor other life forms have designed their spread into new ecosystems. Both economies and ecosystems are notorious for their incompatibility with central planning. Even large-scale agriculture is not a clockwork mechanism, but a continuous and ever-changing act of fostering desired organisms and discouraging undesired ones. Markets can be influenced, fostered, encouraged, and discouraged, but they are collective, emergent behaviors and not, despite how we talk about them, things to create. We lack a vocabulary for discussing this thing we share, the space enterprise, the space movement, that reflects this organic, evolutionary, market-oriented character, and I will inevitably use design-oriented, mechanistic language here because that is all I have to work with.

Space has had many beneficial impacts on human civilization so far—both psychological and because of valuable information (pictures, communications, navigation, and timing) transmitted from, or through, space. But it has had at most a modest economic effect on the totality of human civilization. For space truly to address the challenges human civilization faces, and to enable the continued growth in the well-being and freedom of action by individuals, it has to enter a period of sustained economic growth. Today, there is essentially NO space-based economic activity. If I visit Antarctica, my visit contributes to the GDP of many nations—Antarctica not being among them. I take nothing from Antarctica but pictures, I leave nothing but footprints, and every product or service I would purchase, I get from somewhere else. Antarctic tourism is a small industry, and one enabled by the existence of Antarctica, but not one that can grow organically. And so it will remain while everything done there is packed in and packed out. Similarly, Apollo, for all it taught us, left no economic improvements behind.

For space to scale to the level where it materially improves the common lot of human individuals, it has to grow substantially, and that means we will need to take steps to enable it to grow organically, without ever-increasing subsidies from Earth. That means that we have to begin to gather the energy and material resources of space and transform them into valuable products and services with at least some of the value-added steps taking place in space, and that these capabilities need to be able to leverage each other to increase their capacity with an ever-decreasing fraction of the required investments coming from Earth. I prefer to talk in these terms of economic development, which is broader than settlement.

Settlement, however, is an inescapable part of the process. For the space sector to add economic value to the Earth, it first has to have things of economic value. A trading relationship requires partners on each side. If the space sector is exporting goods or services to the Earth, then some entity in the space sector has to have owned them before it traded them. It is very difficult to envision that scaling up to significant levels without some people in the space sector—people who live there, work there, and own things there. People have unique properties in an economy. They have desires—not always predictable ones. They are not satisfied forever with the bare minimum of existence—they want other services. They do not work contentedly during every waking hour at assigned tasks—they demand leisure, which creates the possibility that they may do things during that leisure that no planner would predict, including creating new things of value and saving surpluses to reinvest in new activities. People grow their numbers, if the resources permit, allowing the space sector to grow organically. However, people cannot exist for long without other life around them, without bringing a biosphere with them, and so the spread of individual people and the spread of life to currently lifeless areas beyond Earth are inextricably linked.

Having discussed what makes a future scenario more desirable, what needs doing to make desirable scenarios more probable, and how can education and research play a beneficial role?

Broadly speaking, if we want economic growth in space, we have to make it worthwhile for individuals, singly or collectively, to do things. That means lowering the costs of going there and doing things and improving the benefits to be gained. There are also existing benefits we get from space, in the form of non-tangible psychological benefits, a sense of available space (which may overlap with the Overview Effect), and in terms of scientific knowledge. Not only are those valuable in their own right, but they also have existing stakeholders who will fight to protect them, and we have to attend to their interests if we wish to proceed. Broadly, then, the main areas seem to me to be:

1) lowering the cost of access to, and through, space;
2) growing the market for space services, especially human services, and the infrastructure that provides them;
3) increasing the returns from space development; and
4) expanding the zone of human exploration and science.

While space is a technological endeavor, many of these require approaches that touch on domains far from those of engineers and scientists.

Lowering the Cost of Access

Lower cost of access to space has long been recognized as the foundational requirement for economic development of space—you have to be able to get there, and the cheaper getting there is, the more things are worth doing. Not so widely recognized is that this is primarily a problem of low existing *demand* for space transportation. Worldwide space launch traffic is on the rough order of 1,000 metric tons/year (roughly ten 747 flights' worth). It was this, and not any lack of technological vision, that held back investment in newer space transportation technology—governments and companies both recognized that existing markets did not justify further investment.

Because space has been so expensive, most things done in space are things we cannot do any other way—if we could, we would. The converse of that is that the elasticity of the market is very low—if space were 20% cheaper, would we launch 20% more communications satellites, or weather satellites, or GPS satellites? So far, the answer has been no.

On the other hand, with very large changes in price (an order of magnitude), it is easy to think of new things we would do—tourism, manufacturing, energy collection, and some in-space assembly of satellites.

This suggests the existence of a "U-shaped" market elasticity curve (Figure 1; the values on the charts below are my own and are highly speculative).

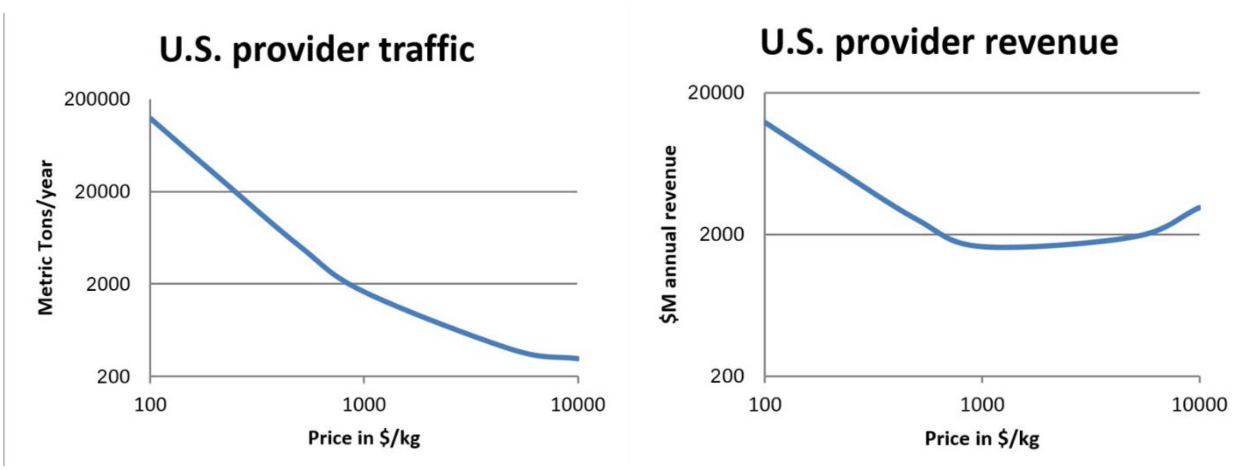

Figure 1. Market elasticity in space

In the last ten years, large speculative investments have been made by private entities (most notably SpaceX and Blue Origin, but also by many smaller firms) in improving space transportation capabilities. This has resulted, for the first time, in published pricing and direct price competition between providers, and a substantial drop in price to roughly $2,000/kg. Since it takes about $1 billion/year to keep a launch company in business, and since the highest volume company sells about 20 launches/year at a price around $60 million, and there are four large and scores of small companies competing in this market, it is clear that what we need is an increase in demand.

It may be that at the current price, new markets will emerge that kick us over to the positive-elasticity region of the curve, and that space transportation will begin a self-reinforcing cycle of higher traffic and lower prices. It is also possible that one or more providers will eventually drop out of the market and that what we have now will be the best we get for a while.

For a technological solution to work at the current market, we would need either a space launch system that shared its costs with non-space markets, or one that allowed a much smaller company to provide comparable launch services. Those are both ripe fields for invention, both of new business models and of new, non-rocket technologies, and both are beginning to be explored.

But the surest way to get to lower prices, for any technology, is to grow the market.

Grow the Market for Space Services, Especially Human Services

A big change in space activity that increases the demand for launch would, by itself, essentially kick us over to an organic growth curve. Any new market, or aggregation of new markets, that required 5,000 tons/year or more of payload and made a profit doing it would probably be enough. This is an area with not enough attention paid to it, and not enough business cases being dreamed up to explore it.

This is especially interesting, because even if the present space launch situation turns out to be a speculative bubble, propped up by a combination of individual and national interests prompting over-investment, the result will doubtless be price competition in launch—which means there is going to be a lot of cheap launch capacity around for a while. And if people find uses for all that cheap launch capacity that make money, the temporary situation will become permanent, and launches will stay cheap and keep getting cheaper, as people keep struggling to win market share in a growing traffic model.

We are not used to thinking in terms of thousands of tons in space. We should be thinking bigger. The challenge of course is that right now, any given space venture essentially has to create the entire value chain—make its own power, bring its own structures, design its own spacecraft, etc. That is a daunting task on Earth, and it is worse in space.

One approach is to find markets that are lucrative enough that they pay for all of that, a sort of boom-town model. Another approach is to design market-aiding mechanisms. I have toyed with the concept of a futures market in space services, allowing people to trade in things like rocket propellant FOB a storage node, with insurance hedges to ensure that someone depending on the product can get it when they need it, even if speculative future services do not materialize. The same could be extended to items like electrical power supplies or transportation services. This is an area of great promise that does not need a billionaire to solve.

The biggest step change in market dynamics would be for human beings in space to switch from being a cost center to a profit center. If launching people to space made money, we would launch a lot of them. Today, there is no way to pay for labor in space. It is, literally, priceless. The emergence of market pricing in launch and in satellite components has been revolutionary in introducing competition, and there is every prospect that the same would be true in space. But then, the people doing that work have to be free to do it—not constrained by their government contracting agreements from doing it. Early applications for human labor in space may not all be noble or high-minded things—they might include filming commercials, making movies or other media products, or doing research in competitive fields where company secrets are important.

Any innovation, technical or business, that lowers the cost of keeping people in space improves the cost/benefit ratio. That covers infrastructure, improved life support, lower mass radiation shielding, more cost-effective habitat designs, new ideas for gathering energy, improved use of in-situ resources. Even the simplest questions are surprisingly poorly studied. Do plants need illumination during a lunar night of 14 days—and if so, how much? That can be studied in a greenhouse on Earth—and yet data is hard to come by.

There is no question in my mind that people can be economically valuable in space. A large part of the expense of satellites is in the actuators that unfold a satellite from a compact and rugged package for launch to a large and rather fragile useful form. A technician in a suitable facility who did nothing other than plug modules together and unfold solar panels could probably generate tens of millions of dollars a year in economic value. The challenge is again one of minimum volume. Putting up a habitat, servicing it, and transporting people to it at present prices is an expensive enterprise. The first for-hire astronaut in space is expensive. The tenth, not so much. If we could think of something that needed ten people in space that made money, they would be affordable.

Ample thought has gone into what we would do with hundreds or thousands of people in space habitats, perhaps not enough has gone on what we would do that made economic sense with ten.

There is no doubt that the long-run promise of energy and materials from space is there; I save them for the last because what has made them difficult is, again, the need to create an entire end-to-end value chain, including some of the in-space transportation services. If someone can think of a way to make even modest profits from them by exploiting thousands of tons of cheap launches, those business cases should be discussed, debated, and vetted, and investment sources could be educated about them. There are huge psychological barriers to making those investments today, simply because no one wants to be laughed at for making them. We need to find ways to make the laughter stop.

Finally, once there is even one material product or human-provided service that is profitable in space, all the others will be dramatically easier to introduce to the market, because the second entrant will not have to provide all the end-to-end pieces of the value chain and infrastructure. The marginal cost of introducing a second product is nearly negligible compared to the investment to get the first one. Space economics scale up well; it is the initial barriers which are daunting.

Increasing the Returns from Space Development

While space suffers from this planning mindset and vocabulary, the expansion of human presence and even human-supporting ecosystems to uninhabited niches is an integral part of the human experience, though that experience is mostly prehistoric. People reached Australia by some form of watercraft roughly 50,000 years ago, and that was an ecosystem as alien to them as any planet depicted on *Star Trek* might seem to us. The Thule/Inuit people learned to live and work in the frozen regions of the Northern hemisphere ~1,000 years ago, by invention of new techniques including the use of carnivores as draft animals. The Polynesian and their predecessor Lapita cultures spread across reaches of the Pacific, which must have been nearly as daunting to them as space seems to us today, and they learned to bring not just the people, but also their ecosystem of domesticated animals and plants with them to a host of new island environments, adapting their tool-making technology to the resources available in each. The settlement of Iceland has some records, though they are fragmentary, and the settlement of Ascension Island, including the successful transformation of the environment to one that would feed its population, is well documented.

Because of the fragmentary record, nothing one can say about early human settlement efforts is free from controversy. But as best I can tell, there are common threads in many of them, which usually include at least two of the following:

- a drive to gain access to new energy resources (hunting or agricultural land being primarily an energy resource) because the existing population in an area desired more than was available;
- a beneficial property interest by those at home, who stood to gain by contributing the resources to those who went—what, today, we might call real-estate speculation;
- a strategic location that made those at home willing partially to underwrite the sending of those who went to create a new trade route, port of call, or defensible frontier;
- a desire for independence or sovereignty—the Polynesian and Viking societies having evolved a voyaging culture in part because it is cheaper to send out boats filled with a would-be-chief and his followers than it is to have the civil war that results when two would-be-chiefs have their eye on the same throne.

Because of the Cold War framework in which we began the Space Age, we took measures to remove two of the most powerful of these incentives—real-estate property interest and a desire for independence—from the incentive structure. That is a policy issue, and it is something that can be corrected in the policy domain. There are many possible approaches to solving it, and they do not all require an international framework—for example, agreements among a few market-oriented spacefaring nations for a method of title valid within those nations might be sufficient. We ignore the need for a framework for some kind of independence at our peril—who can doubt that if there were a framework to achieve that, people would be gathering the resources to claim it?

These are questions informed as much by history and by economics as by science and technology. A great deal of the discussion in this area is by academics who are far removed from practical realities, and there is a great hostility to market economics among many actors in international organizations. The problem of wanting to design or plan things centrally rather than structuring a framework in which they can evolve is very strong here. Evolving a new vocabulary, a new framework for thinking about these questions, not in terms of design, but in terms of market dynamics and evolutionary processes, is a fruitful domain for education and research by and for practical workers in the field

I believe that a framework for independence, or at least partial sovereignty, can be rooted, ethically, in the right of self-determination. If people are living in a space habitat, or on a planetary body, surely, it is first and foremost up to them to decide how to live their lives, and not to those on some other planet. If we fail to recognize that and prepare for it, we are decreasing incentives for economic development in space and sowing the seeds of future conflict.

A point I think needs much broader recognition and dissemination is that it is clearly not true that by raising barriers to property ownership or sovereignty, we are somehow preventing them. We are simply raising the price. It is unlikely that nation states that have blatantly disregarded other international agreements, such as the Law of the Sea Treaty, will let the Outer Space Treaty stop them from making territorial claims in space. Multibillionaires who do not need the approval of broad investor bases are also not likely to be restrained from making, and defending, property claims. The absence of legal structures for these things simply means they will be the preserve of those willing to use older tools, like force. The only people restrained from acting in space by these structures are those in relatively free, market-oriented countries with a strong rule of law. There, we have grown used to financing only with clear, defensible title, and acting in smaller groups than nation-states. Creating a structure for property rights and sovereignty democratizes space and makes it available to smaller actors in free societies.

Expanding the Zone of Human Exploration and Science

There is no question that how we think about space constrains what we do with it. It took Apollo for the Moon truly to become a place in our thoughts. It took the analysis of the samples brought back to start to understand some of the resources it might hold—and we missed arguably the most important one, the polar volatiles, which took another generation for people to think of it, look for it, and send several missions to gain ever-greater confidence in their existence. It was not until those resources were found that people began serious consideration of Luna as an economically valuable location.

It is an important part of the process of human expansion to new niches that we must first explore, and then we can settle and begin economic activity. One of the great psychological benefits of space is that, for those who have truly internalized it, it opens the system—we recognize that we are not facing scarcity, but abundance: “it’s raining soup, grab a bucket.” To continue to provide that benefit, there must always be a next destination, a next goal post.

Mars and the asteroids beckon, and beyond them, the outer solar system. We can already guess at some things future generations will think valuable out there. As the population of the Solar system grows off the Earth, nitrogen becomes valuable—abundant in the outer system. As we shift to a fusion-powered economy, the ice giants, Uranus and Neptune, are rich in fusion fuels (deuterium and helium-3). The outer solar system is essentially full of ice.

Furthermore, we are living in the great era of discovery of planets in other solar system; thousands and climbing. It is only a matter of time before we find one about which science and popular sentiment alike cries out, "why can we not send a probe?"

In less glamorous but more fundamental pursuits, science itself is showing signs of stagnation; the great questions are reaching the limits of earthbound laboratories. We need bigger and higher flux particle accelerators. We need to know what dark matter is made of—or if, indeed, there is any such thing. There are alternative theories that we need to test that we can only test in space away from the sun, or by sending instrumented packages to higher speeds. The quantum-mechanical treatment of gravitation eludes us; we might not understand it without observing ultra-dense matter—and the nearest white dwarf is 8.6 light years away. The universe is a great laboratory awaiting experimenters.

To unlock those frontiers, we absolutely require better propulsion. The limits of chemical rockets have been reached (as was clear to all that they would be, as far back as Tsiolkovsky). The field of possible options is very rich. Very few realize how rich it is. It is hard for the general public to understand that we have spent less on improving propulsion in the last few decades than we have spent on any one of the missions that would benefit from improved propulsion. Mars in months, the outer solar system in a year rather than a decade, even missions to send probes to other stars in the time that the Voyager spacecraft have been flying are all things we can see ways to do.

On a less lofty note, in the decades during and since World War II, Big Science has become an interest group, or lobby, of significant political power. This has produced some notable accomplishments, but it also creates the danger that when there is a large, powerful group involved in studying something, it does not look favorably on alternative approaches. For example, we have spent more on studying the effects of microgravity on humans than it would take to provide artificial gravity for humans. There is a strong view among the space science community that humans should not visit Mars—or at least not until the scientists are done studying it. If we want to expand the sphere of human economic activity, we have no choice but to keep the supply of scientifically interesting questions replenished, or else we will create a conflict between interests, resulting in both less science and less economic activity than we otherwise could have.

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About the Author: Jeff Greason is an entrepreneur and innovator with 22 years' experience in the commercial space industry. He is the chief technologist at Electric Sky, developing long-range wireless power for propulsion and other purposes; and Chairman of the Tau Zero Foundation, developing advanced propulsion technologies for solar system and interstellar missions. He has been active in the development of commercial space regulation and served on the Augustine Commission in 2009. Jeff was a cofounder of XCOR Aerospace, and he served as CEO from 1999 to early 2015. Previously, he was the rocket engine team lead at Rotary Rocket, and an engineering manager in chip technology development at Intel. He holds 25 US Patents. He is also a Governor of the National Space Society.

Editors' Notes: Jeff Greason has been recognized for years as one of America's outstanding Space experts. He has contributed to both government agency and commercial Space company policy and study efforts. Kepler Space Institute's (KSI) academics will benefit greatly by his joining the faculty. In this essay he includes a host of Space subjects that will need more research and inclusion in the *Journal of Space Philosophy*. ***Bob Krone and Gordon Arthur.***

Supercollider Exhibition: Space Science and Art

By Bob Krone, Richelle Gribble, and Salena Gregory-Krone

Art is already a valuable component for every mission in the Space Epoch now experiencing a robust 21st-century beginning.

Bob and Salena Krone attended the opening reception of *A Message to Space* this January 8, 2020 at *SUPERCOLLIDER,* a new art + sci + tech gallery and satellite exhibition platform. This exhibit took place at the Mothership (HQ), based in Los Angeles, California. Space artist, Richelle Gribble is the founding director of this gallery, leading curations worldwide.

SUPERCOLLIDER's mission is to create art exhibitions to reflect these times of rapid change and to serve as prototypes for progressive futures. Affiliated institutions include the Carnegie Mellon Institute, NASA, BioBAT Art Space, Planet Labs, SciArt Initiative, Biosphere 2, and Beyond Earth.

Richelle Gribble, Founder of *SUPERCOLLIDER*

A Message to Space brings to public awareness notable art and science projects interacting with and exploring outer space. Artworks etched onto satellites, artworks created by astronauts, artifacts that have flown to space and back, and pumpkin seeds flown in low Earth orbit— these works convey that the pursuit of understand life on earth and beyond is not so distinct from the artist's quest to understand life's meaning.

This exhibition featured the *Space Art DNA Time Capsule*, an art project that will store drawings and messages on synthetic DNA and then rocket the DNA to outer space in 2021. For this project, the gallery provided drawing materials for guests to submit works during the exhibition opening.

The exhibition also presented artworks by Nina Waisman, Director of the Laboratory for Embodied Intelligences and recent exhibitor at the Hammer Museum; a celestial musical performance by harpist and singer Zeraphina Quenby with a live performance of "Space

Oddity" by David Bowie; and Nicole Stott, NASA astronaut, contributed the "Exploration" space suits made through the collaborative efforts of the Space for Art Foundation.

Salena Gregory-Krone happy about Nicole Stott's Art Space Suit.

> I am really excited about the SUPERCOLLIDER concept for bringing art and science together, and especially excited about the space and art theme. (Nicole Stott, NASA Astronaut)
>
> Galleries like SUPERCOLLIDER are essential in today's culture; art which engages science and technology in a serious and rigorous way is the avant garde of the art world. (Julia Buntaine, Director, SciArt Initiative)
>
> It is great to finally have a gallery in the Los Angeles community that is dedicated to art and science collaborative projects! (Victoria Vesna, Director, UCLA Art Sci Center)

Art has been the medium for expressing the essence of humanity's existence for good or bad. One of the facts about humans in Space is that *The Overview Effect*,[1] first described by Frank White and illustrated in a mural by Richelle Gribble, is changing the way we humans perceive our planet.

The images we have in our brains have more impact on our cognition than the words we hear or read. The Overview Effect describes the images from Space of Earth without boundaries, without human intolerance or discrimination, and without the values biases that are fixed into Earth's tribalism of multiple societies, groups, organizations, and politics. None of those human pathologies exist now in Space. Our vision is that they can

[1]Author Frank White created the Overview Institute, published the book, *The Overview Effect:Space Exploration and Human Evolution* first in 1987, and the third edition in 2014. The book captures the feelings and new insights of astronauts who have viewed the Earth from Space. Frank lectures extensively and is a Kepler Space Institute Professor.

be avoided as human Space Settlement occurs. Achieving that goal will be one of Space Exploration's huge challenges.

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About the Authors: **Bob Krone, PhD**, is President of Kepler Space Institute (KSI); Emeritus Professor of the University of Southern California; Colonel, USAF (Ret); PhD/DBA Degree Supervisor; Doctor of Laws, Honoris Causa, La Sierra University, Riverside, California. His wife, **Salena Gregory-Krone, GM-11(Ret),** was an American Civil Rights Leader, is an author and a KSI Research Associate. **Richelle Gribble** is a multidisciplinary and international artist having completed 16 art residencies in which she travels the world to record social and environmental changes artistically. She is an Idyllwild Arts Alumnus and Scholar with KSI.

Salena Gregory-Krone, Richelle Gribble, Bob Krone
SUPERCOLLIDER, Los Angeles, CA, January 8, 2020

Editor's Notes: This article highlights that art offers another window through which to view human endeavour in space, particularly when it is combined with science in an attempt to develop understanding. This fits in well with the objectives of the *Journal of Space Philosophy*. ***Gordon Arthur*.**

Space Paradigm Shift

By Stevan Akerley

Editors' Note: This article was received before the coronavirus emerged in China.

Abstract

There has been a significant change in our perspective of the Moon, how to get there, how much it will cost, and what to do when we get there. This paper examines some of those changes, and it looks at how the changes in rocket technology provide a paradigm shift for space exploration (mainly the Falcon 9, and proposed SpaceX StarShip and Super Heavy Booster). The paper explores the opportunity to use a consortium of government, commercial, and private entities to open up access to the Moon, and to provide a new commercial capability both on the lunar surface and in cis-lunar space, to manufacture useful resources to support human expansion into space. The paper uses several NASA reports as a base example, and it modifies them to show how a consortium approach could open up and expand our current efforts in space. This paper is meant to be an exploratory introduction to how we can shift our thinking to accomplish much more in space than we have to date. More work is required to refine the ideas in this paper, but the next ten (or twenty?) years hold much promise for a surge in space activities, I believe.

Introduction

Over the last sixty-seven years we have watched the US-NASA space program evolve from Mercury, Gemini, Apollo, and the Space Shuttle to the International Space Station, but we have been stuck in low Earth orbit (LEO) for the last fifty years. There were many successes we took pride in, both manned and robotic, and some failures, with loss of life that saddened and disappointed us. In the last twenty years there have been several satellite probes, by various nations, that have been sent to study the Moon, that have revealed surprises, and that have showed that we had a lot more to learn about the Moon. The quote, "been there, done that," was hollow and uninformed: we had not seen very much, and we had not done what we needed to do.

Change is happening, and there are at least six countries working on plans to return to the Moon, to stay and make use of it. There are many more companies actively involved in these plans to return to the Moon, making hardware and providing services to support various activities. This paper discusses some of these changes and makes some recommendations on what to do when we get to the Moon.

Overview – Paradigm Shift

There is a rocket launch paradigm shift that is revolutionary to the aerospace industry and space access in particular. The traditional aerospace companies that make hardware for NASA, the military, and commercial space activities have been surprised by a new set of start-up companies (new space) over the last decade. These orbital launch companies include SpaceX, Blue Origin, Bigelow Aerospace, and others, as well as the existing aerospace companies, which are having to change to compete.

Some of these new companies have been funded and are run by new age billionaires, who are using patient capital to finance their company activities. Each of these companies faces its own individual problems in getting started and running as an ongoing business. First and foremost is the business case for a new business with a high cost of entry, technical problems that cause failures of hardware, and losses that cause near failures of the business. Then, developing the final products and services to provide an ongoing business plan and securing paying customers. The historical record for these start-up rocket launch companies shows many failures and few successes.

An interesting success story for SpaceX in developing the Falcon family of rockets is a good case example. There are books written about the historic rise of SpaceX and its CEO and Technical Officer, Elon Musk, so we will not dwell on these details here. In short, SpaceX would have gone bankrupt if its third launch of the Falcon 1 had not been successful. However, SpaceX is not only running a successful launch business today with the Falcon 9 (F9) series of rockets, but also developing a new, larger rocket called the StarShip and Super Heavy Booster—(SS/SHB). All the F9 and the Falcon 9 Heavy (F9H) rockets have reusable first-stage boosters that land vertically back at the launch facility for easy refurbishment and relaunch, without any other significant transportation requirement. The SS/SHB is another revolutionary advance over, and on top of, the success story of the F9 and F9H. It will offer not only heavier launch capability than any other rocket planned today, but also both the first-stage booster and the second stage to orbit will be totally reusable, and the second stage will be refueled in orbit. This two-stage-to-orbit system will make the F9 and F9H obsolete in the long run, although these two Falcon rocket designs have reusable first stages and are therefore superior in both launch cost and performance to the other expendable launch vehicles. Table 1 gives the launch systems costs.

If the SpaceX SS/SHB is successful, and there are many who hope it will be, it will blow open the doors to accessing Earth orbit, cis-lunar space, the Moon, and Mars. The ability to launch heavier cargo into orbit at lower cost and to land heavier cargo on the Moon and Mars will make it possible to do many things we have only been able to dream about before: launch larger and more space stations, use space solar power, and set up and operate multiple lunar bases to continue and accelerate the exploration started half a century ago and to start learning how to use the lunar resources. As the lunar bases become operational and successful, the amount of traffic between Earth and the Moon will increase and the need for services and activity in Earth orbits and cis-lunar space will increase, particularly near the Lagrange points and other strategic orbits. As lunar resources become available, the lower cost of getting those resources from the Moon into cis-lunar space will further accelerate space activities.

Table 1. Launch Cost Estimates[1]

Launch System	Cost of Launch	Mass to LEO Expended (lbs.)	Mass to LEO Recovered (lbs.)	Mass to GEO Expended (lbs.)	Mass to GEO Recovered (lbs.)	Mass to Moon (lbs.)	Mass to Mars	Cost/lb. to LEO	Comments
Shuttle–STS	$1,600,000,000		60,600					$26,403	Max cost
Shuttle–STS	$606,000,000	N/A	60,600	N/A	N/A	N/A	N/A	$10,000	Empty orbiter (165,000 lbs.)
Space Launch System (SLS)	$2,000,000,000		150,000					$13,333	Max cost
SLS–Block 1	$1,000,000,000	120,000				81,571		$8,333	Manned: 37 tons (81,571 lbs.) to deep space including Orion and its crew
SLS–Block 2	$1,000,000,000	150,000				99,000		$6,667	Cargo: 45 tons (99,000 lbs.) to deep space
Ariane 5	$165,000,000	44,000	N/A					$3,750	
Proton M (UR-500)	$65,000,000	23,000	N/A					$2,826	
Atlas V–United Launch Alliance	$110,000,000	42,000	N/A		N/A	N/A	N/A	$2,619	Could have as many as five solid boosters
Vulcan	$99,000,000		39,160					$2,528	
Falcon 9–SpaceX	$62,000,000	23,100	23,100	9,914	N/A	N/A	N/A	$2,684	Launch costs can be as low as $50M
Falcon 9 Heavy–SpaceX (Max)	$150,000,000	141,000		N/A	N/A			$1,064	

[1] Source: en.wikipedia.org/wiki/Comparison_of_orbital_launcher_families.

Launch System	Cost of Launch	Mass to LEO Expended (lbs.)	Mass to LEO Recovered (lbs.)	Mass to GEO Expended (lbs.)	Mass to GEO Recovered (lbs.)	Mass to Moon (lbs.)	Mass to Mars	Cost/lb. to LEO	Comments
Falcon 9 Heavy–SpaceX	$90,000,000	141,000	141,000	57,278	17,624	37,010		$638	$150M total, $1,063/lb. based on two launches
Big Falcon Rocket–SpaceX (Max)	$300,000,000	N/A	330,000	N/A	N/A	220,000		$909	"But even if the BFR launch costs were half of the shuttle launch costs, the cost per lb. would still be less than $1,000 with greatly increased capacity and capability"
Big Falcon Rocket	$200,000,000	N/A	N/A	N/A	N/A	220,000		$909	
Big Falcon Rocket–SpaceX	$165,000,000	N/A	330,000	N/A	N/A	220,000		$500	"$500/lb. to orbit would be ideal target. On orbit, refueling required–Depots?"
Blue Origin–New Glenn	$100,000,000		99,000		29,000			$1,010	Costs $2.5 billion and will fly 25-100 times

The lunar and cis-lunar space experiences will be an important test of hardware, people, services, and failures that will flow into and enhance the Mars research bases when they are started. The result will be a cascade of events over the following decades, as business opportunities unfold to support the demand for space exploration and the utilization of materials and services to support Earth's needs. Along with this expansion will come space settlement.

As the development of the SS/SHB (now called StarShip) continues, there will be significant risks, both technical and business. The initial new engine for the SS/SHB (the Raptor) has been designed and build and it has had its first flight test in a test vehicle called the Starhopper, on August 27, 2019, validating its initial performance parameters.[2] If prototype tests go as planned, operational StarShip flights with payloads could begin as early as 2021. A StarShip has been booked for a flight to the moon and back for 2023.[3]

One of the most important risks to the StarShip development effort is the general economic condition of the aerospace industry. If the economy suffers a serious recession and there are other distractions like wars, the currently available critical resources may be redirected, and thus stall the development work. Once the StarShip is developed, there will be another risk: to develop the customers and markets for its use. There will need to be a very big business base and high demand to justify the design and operating expenses of the StarShip. The StarShip is not required for a lot of the current launch business activities. The F9 and F9H are taking on that business very well. The StarShip *is* required to get to the Moon and Mars, and to support cis-lunar space and lunar base activities.

The StarShip is an *enabler* for accelerating human activity in space. The new heavy lift capability will accelerate exploration and science projects, and it will make it possible to have basic and heavy industry as well. The heavy-lift capability will make it possible to bring first-generation capital equipment from Earth to the Moon (more about this later).

Lower capacity rockets with a limited payload and higher cost, have forced us to execute expeditionary programs, with minimal if any infrastructure to support continuing and expanding activity. Even with the NASA SLS launch system, there is little infrastructure planned in space or on the Moon. To use lunar in-situ resources (ISRU) in a significant way, we will need to place resource processing facilities on the Moon, and to be able to refine and transport them back into cis-lunar space to appropriate depots.

I am reminded of the development efforts for very large aircraft, the resulting teething pains technically, and the business and market demand shortfalls. The aircraft of interest are the Boeing 747, Lockheed C-5A, and Airbus A380. I was actively involved in

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[2] See Guy Norris, "SpaceX's Starhopper Verifies Raptor Performance for StarShip," *AWST*, September 2-15, 2019.

[3] On November 30, 2019, StarShip Mk1, which was being built in Texas, suffered a fatal failure when being tested with cryogenic fluids. It was an explosive failure, with the ship destroyed. StarShip Mk2, being built in Florida with the same design, was terminated. A new StarShip Mk3 started construction in Texas. Videos are available online.

manufacturing, quality, and mass properties for two of these aircraft, and I read a lot about the third. The C-5A is no longer in production. The Boeing 747 is still in production (after fifty years), and it has gone through several redesigns to stay relevant, but it seems to be the right size: not as big as the Airbus A380. Currently, the A380 is still in production, but probably not for long. The market demand for these large aircraft is changing again, and airlines are looking for smaller aircraft to serve shorter routes more cost effectively. Production termination will occur before Airbus has fully amortized its development and production costs. This could be a warning example for the SS/SHB. Competition will heat up, and there will be a next, follow-on generation of even larger rockets.

A review of current (large) rocket launch systems reveals a significant difference between each of them and their market potentials. In general, some of the older rocket designs are more expensive than the newer designs, since the industry has been trying to reduce costs on a continuous basis. It is clear from Table 1 that the new rocket competitive launch costs to LEO will be in the $500/lb. to $1,000/lb. range, and this will only be possible with reusable rocket boosters with easy turnaround (i.e., vertical landing at launch facilities). Expendable rockets will not be cost competitive in the future, perhaps even sooner than expected. It is questionable how cost effective and productive the SLS, being developed by NASA, will be, given the new age rocket company systems and their competitive advantage. Also, the launch cost has come down with smaller rocket systems like the Electron as well, and other new systems are coming online.

Some observations about SpaceX F9, F9H, and United Launch Alliance (ULA) Atlas V.

1. There is a paradigm shift in the way SpaceX has developed and is operating the Falcon 9 *reusable* rocket systems (Both F9 and F9H).

2. The costs are well below the traditional learning curve because the rockets are not thrown away.

3 They can choose to price competitively with ULA Atlas V system, making a lower bid, thus maximizing their profit and satisfying customers at the same time.

4 For larger launch customers, the F9H can launch below ULA Atlas V systems costs for a bigger market share, thus denying their competition that part of the business or initially securing a higher profit.

5. If the SS/SHB can reduce costs below F9H, as predicted, then we could see $500/lb. to $1,000/lb. launch costs (potential short-term monopoly?). SS/SHB launch capacity would also more than double.

6. SS/SHB easily has the range to reach the Moon and Mars if there are refueling depots in cis-lunar space.

7. Blue Origin and New Glenn will need to compete cost-wise with the F9H initially, and then with the SS/SHB.

8. Perhaps Blue Origin's plans for New Armstrong will be competitive in cost and lift capacity with the SS/SHB.

Table 1 shows the costs/lb. to LEO in relation to the older rocket systems, but also the effect of reusability. There is some variation in these numbers, so a minimum and maximum cost trend is shown, clearly leading to a $500 to $1,000 cost per pound to orbit mentioned earlier. Over the next twenty years, this should reduce even more.

Lower Launch Costs
Figure 1 shows the maximum/minimum cost curves to LEO for the various launch systems.

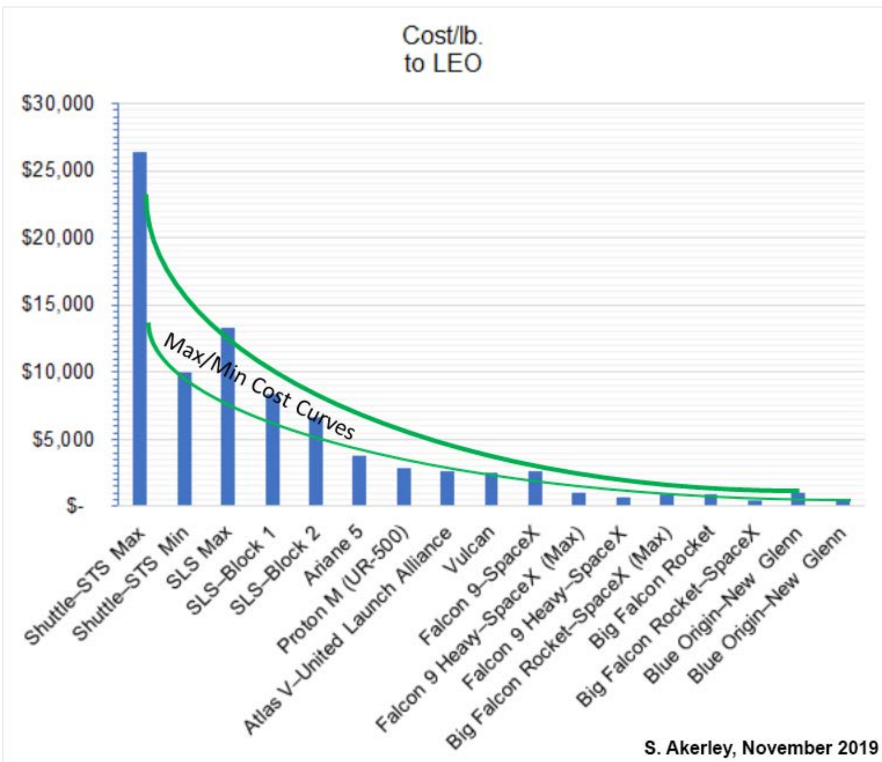

Figure 1. Maximum/minimum cost curves for several launch systems.

As the rate of launch frequency increases, high reusability of launch hardware and competition improvement will occur over time, and the cost of the hardware will experience a learning curve cost reduction. So, with experience and higher usage of reusable systems, we should expect these costs to decrease further. This phenomenon is well known, and Figure 2 expresses it well.

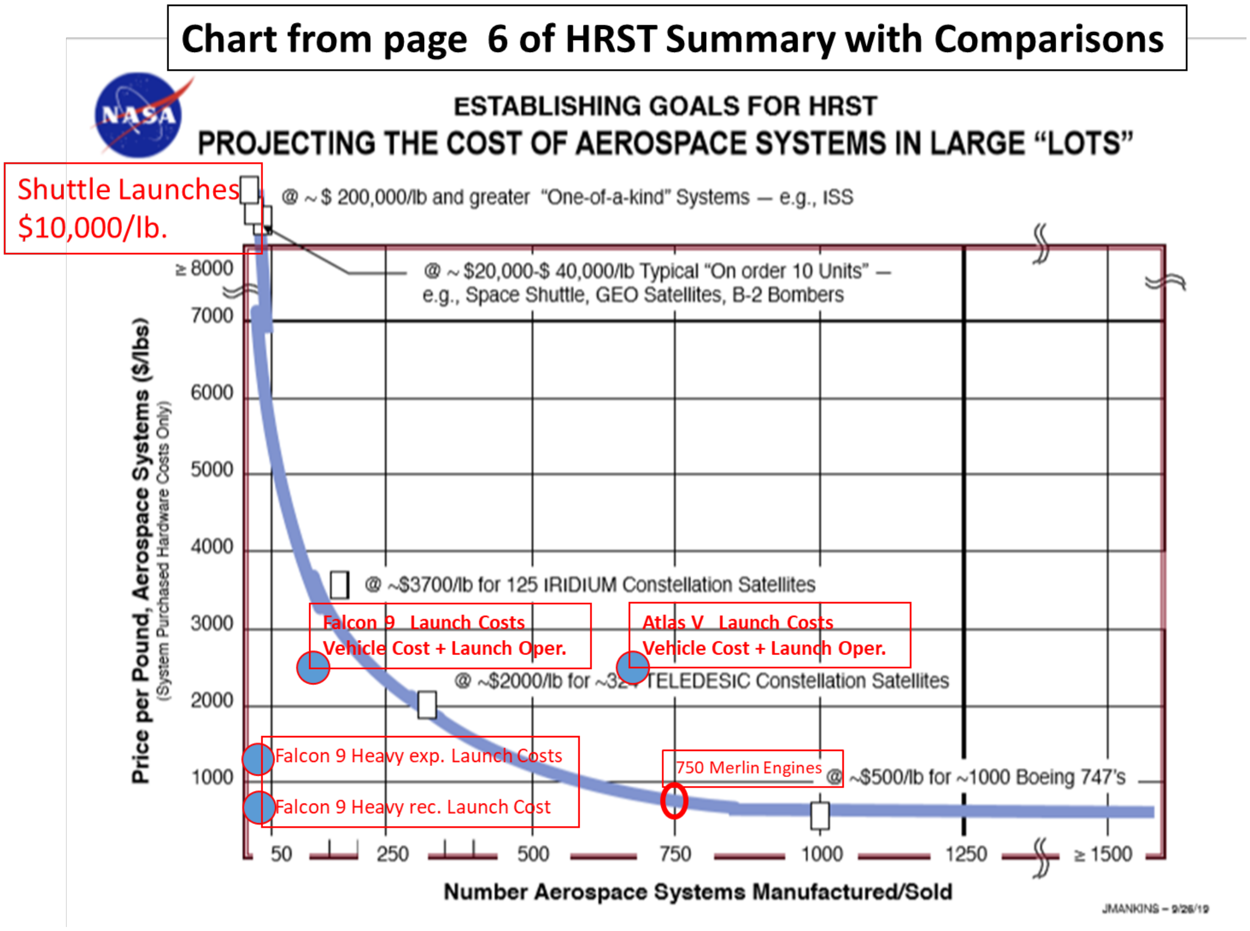

Figure 2. Cost curves for several launch systems.

This particular learning curve example was taken from a NASA study for a highly reusable space transportation system, and it was created in 1998. It has taken two decades to get to the point where reusability is a reality and can reduce launch costs. The next hurdle will be to increase reusability and safety, thus reducing system and operations costs further.

Note that the learning curve has some notional entries in red that show some examples and thought exercises about system costs. The cost of launching an Atlas rocket has improved over its life, but it is at the end of its useful design life, which is why the ULA is developing its new rocket the Vulcan (included in the chart). Although the listed launch cost of the F9 is just a little lower than the cost of an Atlas launch, there is probably a larger profit margin for the F9, as it is a much newer system, and it can easily compete with the older Atlas system. It has been observed that all of the F9 rockets have a cost and operations advantage, in that there have been more than 750 Merlin engines produced, with associated learning in manufacturing and operations improvements, which gives an additional reason for the lower cost of the F9 rocket, and its reliability. Additionally, the F9 rocket has improved engine sensors on its nine engines, and a high degree of flight automation that improves both safety and operations costs.

Figure 3 comes from a NASA report from 2003, titled *Cost Considerations to Ambitious Human/Robotic Exploration*.[4] The chart is based on the 100-day class missions, for example, a human lunar return ETO transport. Figure 3 shows that some of the base assumptions have changed, as we no longer have the Shuttle or Titan IV in the lower chart line. However, the cost model is still a good historical example of the reality of the last decades, which we then use to consider some of the changes.

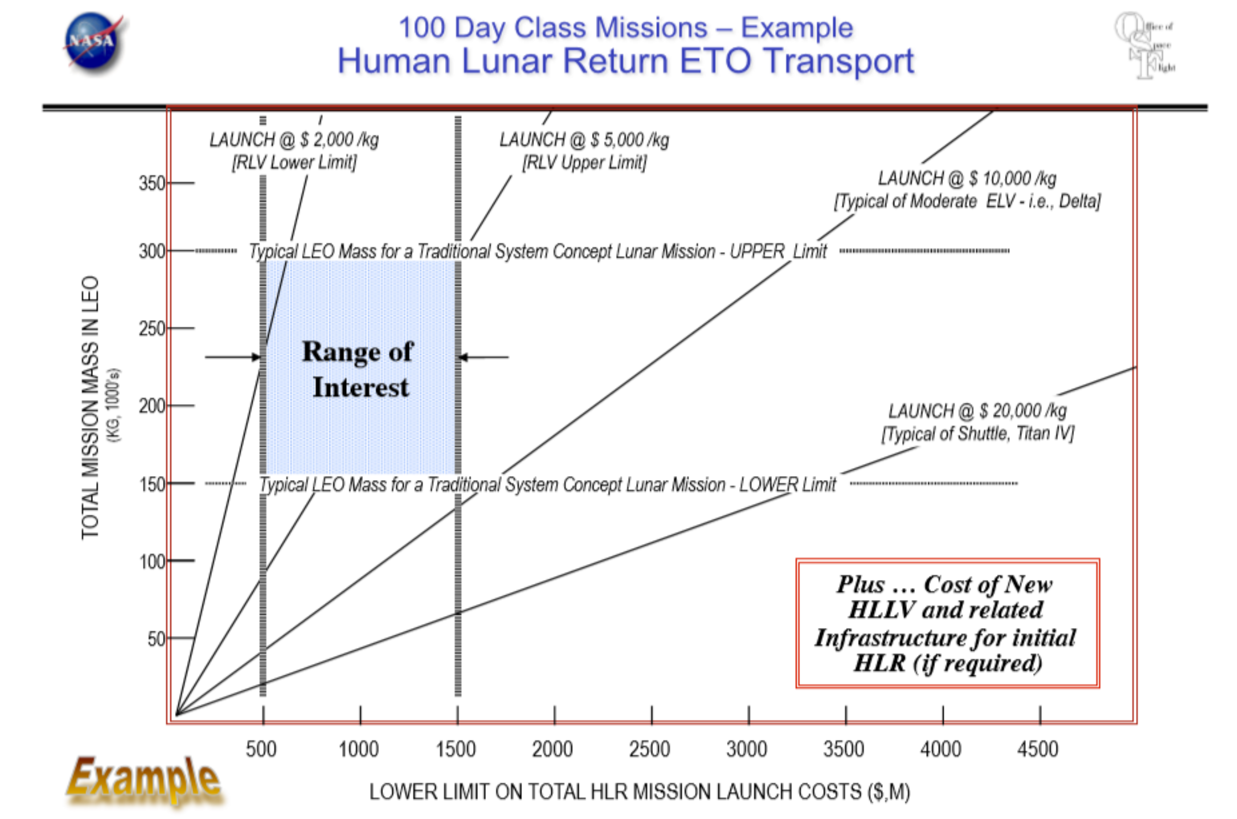

Figure 3. Costs of various options for a human lunar return mission.

In Figure 4, there is added data that is relevant to the new SpaceX vehicle (SS/SHB) in red. As is consistent with previous information in this article, there is a new lower cost to orbit than was possible in 2003.

It is notable that the payload lifted to orbit by SS/SHB is much more than was possible previously. The cost of lifting that payload has decreased. The resulting missions are less expensive, and they can do more. Even some of the newer rocket systems (F9, F9H) will become less and less competitive as the SS/SHB goes into regular use. This will change what can be done and how it will be done, and it will potentially accelerate when it is done.

[4] John C. Mankins, *Cost Considerations for Ambitious Human/Robotic Exploration—The Need for Transformational Space Infrastructures* (Washington, DC: NASA, 2003).

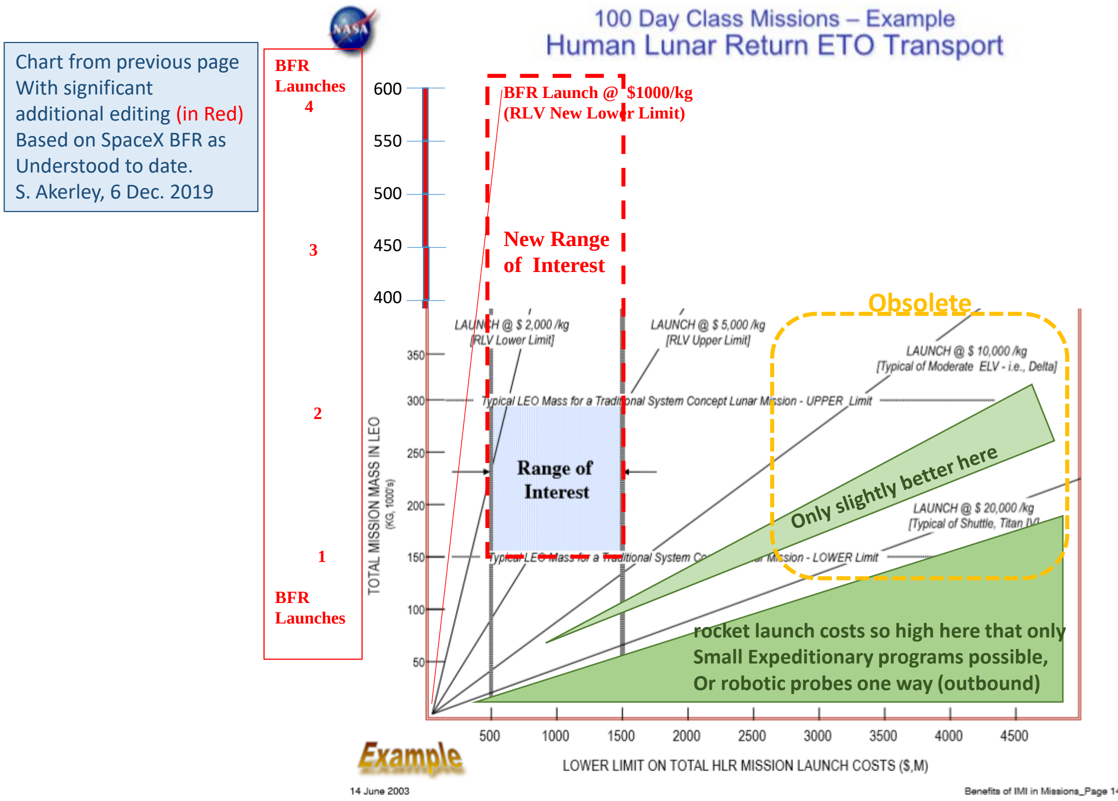

Figure 4. Target costs of various options for a human lunar return mission.

New Opportunities and ΔV

The lower launch costs and increased launch rate will open opportunities for access to space. These new opportunities will expand gradually from LEO outward, to include all cis-lunar space, all the way to the Moon, as outlined below (Figure 5):

Low Earth Orbit (150-1,200 miles altitude [2,000 km])

Medium Earth Orbit (1,200-22,000 miles altitude)

Geosynchronous Earth Orbit (22,236 miles altitude)

High Earth Orbit (above 22,236 miles altitude)

Stations at Lagrange Points and Depots

Lunar Orbit/Gateway

Lunar Surface

And beyond

When we return to the Moon, there are resources that we will want to use for construction projects, and fuel both on the Moon and at depots in cis-lunar space. We will want to do this because it will be less expensive than bringing the same resources up from Earth.

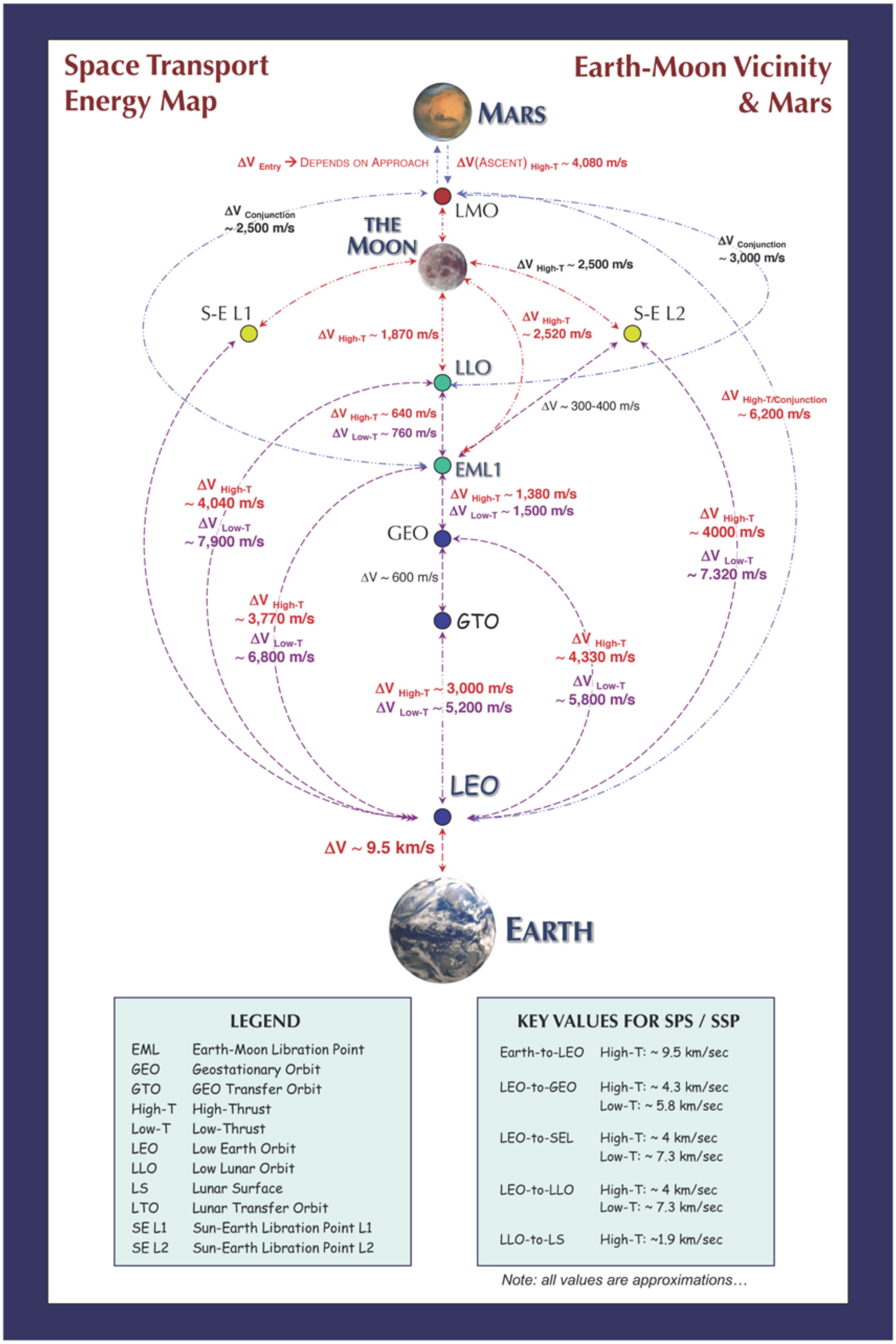

Figure 5. Space energy transport map.

There is a famous quote, by Robert Heinlein; “Once you get to Earth orbit, you are halfway to anywhere in the solar system.” This is a general reference to the amount of energy required to get into Earth orbit vs. travel to any of the planets. An easy and graphical way to see this is by looking at a ΔV chart (change in velocity). An example of such a chart of the Earth Moon System, is the 2019 “Space Transport Energy Map,” provided by John Mankins (Figure 5). Although this is a generalization, it is a good foundation for considering ΔV (velocity roughly correlates to cost) of getting materials from the Moon vs. Earth into space.

Using this ΔV data and assuming a high thrust propulsion system, the energy to reach LEO is the major share of the energy for getting to the moon. Or, conversely, it is easier (energy wise) to get a pound from the lunar surface to the Earth-Moon Lagrange Point 1 (EML1) (2.5 km/s) than from the Earth’s surface to EML1 (9.5 + 3.7= 13.2 km/s), roughly 1/5 the ΔV cost (see Table 2).

Earth to LEO	= 9.5 km/s
LEO to EML1	= 3.7 km/s
EML1 to Lunar Orbit	= 2.5 km/s
LMO to Surface (Descent)	= 1.8 km/s

Table 2. Space Transportation Cost Worksheet (Based on ΔV – Cost per kg)

Transport Leg	ΔV (m/s)
Earth to LEO	9,500
LEO to EML1	3,770
EML1 to Moon	2,520
LMO to Surface (Descent)	1,870
Moon to LMO (Ascent	1,870
LMO to EML1	2,520

	Total ΔV	$/kg	$/lb.
ΔV Earth to Moon Surface	17,660	$2,045	$929.47
ΔV Moon to EML1	4,390	$508	$231.05
Difference	4	4	4

All other cost drivers being equal, the transportation cost of a pound of anything from the Moon to the EML1 location would be one quarter of the cost to get it from Earth. Or, conversely, if you can make it and use it on the Moon, you avoid the excessive transportation cost from Earth. However, the situation is a bit more complicated than that (the cost of ΔV above is based on $500/lb. to LEO; a range of costs is considered later).

Resources (Lunar ISRU)
Table 3 shows the most abundant surface resources on the Moon. Notice that there are many interesting and possibly useful elements, and that the top four are the primary ingredients for concrete cement, but that there is an energy cost to harvest them, refine them, and make them useful.

Table 3. Lunar Surface Chemical Composition[5]

Compound	Formula	Composition	
		Maria	Highlands
Silica	SiO_2	45.4%	45.5%
Alumina	Al_2O_3	14.9%	24.0%
Lime	CaO	11.8%	15.9%
Iron (II) Oxide	FeO	14.1%	5.9%
Magnesia	MgO	9.2%	7.5%
Titanium Dioxide	TiO_2	3.9%	0.6%
Sodium Oxide	Na_2O	0.6%	0.6%
		99.9%	100.0%

The energy cost to process these raw materials into commercially useable resources is in Table 4. Significant amounts of energy are required to process these materials, and a relatively large scale ISRU facility will be necessary to process these materials economically to make meaningful products to support a lunar base, or for activities in cis-lunar space.

One initial idea was to use lunar iron to make and roll steel plate to make tanks to hold volatiles collected and processed at the lunar poles. Another approach would be to use alumina to make aluminum for tankage. However, making aluminum costs considerably more energy than making steel.

Various types and sizes of tanks would be required, but in all cases, it would be cheaper and easier to use lunar materials than to transport the heavy tankage from earth. However, upon researching the required processing steps, a need to bring in a significant amount of equipment to do this becomes apparent. In addition, the equipment has multiple functionality for a wide range of products, so it is obvious that it is possible to provide the lunar base(s) with more than just tankage. So, the business opportunity grows much larger if there is adequate power. The power requirements and transport requirements on the Moon are still significant, even if they are less than those for transporting materials from Earth.

[5] Source: en.wikipedia.org/wiki/Geology_of_the_Moon.

Table 4. Energy Required to Produce 1 kg of Material (Reordered by Energy Required, Grouped by Material)[6]

Material	Source	Energy kWh	Comment	% on Surface
Volatiles	Lunar Poles	TBD	Water and other volatiles (distillation and separation)	In cold trap deposits
Water	Electrolysis	3.66	Separation of oxygen and hydrogen	In cold trap deposits
Oxygen	Bound in Compounds	TBD	Byproduct of baking or refining processes	40
Glass	Sand/Silica	9.70		
Iron	Iron Ore	6.95	Uses lots of carbon—2 kg CO_2	14
Iron	Iron Ore	9.73	Electric anode process[7]	14
Steel	Recycled	4.17		
Steel[8]	Iron	13.90		
Copper	Copper Sulfide Ore	34.70	For aluminum alloy and electrical wiring	
Aluminum[9]	Recycled	4.75		
Aluminum	80/20 Mix	60.80		
Aluminum	Bauxite	95.00	Uses lots of carbon[10]—4 kg CO_2	
Aluminum	Bauxite	171.00	Non-carbon anodes (from 1.2 Volts to 2.2 Volts + 80%)	
Nickel	Ore	75.00		
Titanium	Ore	261.00		
Silicon	Silica	65.30		
Silicon	Electronics Grade Silicon[11]	2,154.90		
Magnesium			Similar to aluminum, but much more energy required	

Upon studying these charts, looking at availability of resources, and looking at energy cost to process, several conclusions can be drawn:

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[6] Source: www.lowtechmagazine.com/what-is-the-embodied-energy-of-materials.html.

[7] Alternative processes for aluminum smelting using inert anode cells (oxygen evolution) include (a) lanthanated tungsten (La_2O_3); (b) MIT chromium iron alloy.

[8] Many companies are using electric arc furnaces to make steel, particularly specialty steel like stainless steel and high-temperature alloys. However, they usually use 40 ton, 80 ton, or larger capacity furnaces. A smaller furnace would be a good candidate for casting iron and steel on the Moon initially. Clearly a higher capacity is possible if the power is available. See en.wikipedia.org/wiki/Electric_arc_furnace.

[9] For the aluminum smelter process, see anscon.com.

[10] See Columbia Climate Center, *Mitigating Emissions from Aluminum* (New York: Columbia University Press, 2012), climate.columbia.edu/files/2012/04/GNCS-Aluminum-Factsheet.pdf.

[11] Martin J. Pitt, "On the Enthalpy of Formation of Silicon," unpublished paper.

- There is a lot of oxygen bound in the compounds on the Moon.
- Silica and alumina are very abundant.
- Iron is #4 in abundance, at 14% in Maria locations (mostly high-quality ore).
- If silica can be found and processed in a relatively pure form, it can be used to make glass. Or, if not so pure, it will be possible to make bricks for construction purposes.
- Iron oxide can be electromagnetically separated from the regolith and it can be processed easily into iron and steel, with appropriate capital equipment for foundry and rolling mills.
- Volatiles at the lunar poles look like the easiest resources to harvest on the Moon. This will be important for obtaining propellant, assuming the processing can be done efficiently.
- Then, the next easiest resources to harvest will be silica and iron (lowest energy to process).
- An electric anode process can be used to smelt aluminum instead of carbon, but 80% more energy would be required.
- An electric anode process can be used to smelt iron instead of carbon, but 40% more energy would be required.
- If water can be obtained (in lava tubes?), then it may be possible to make concrete, since the primary ingredients of cement are available: lime—CaO, alumina—Al_2O_3, and silica—SiO_2.[12]

Initial harvesting of volatiles at the poles, at the top of the resources table, will be relatively inexpensive, but it will initially require bringing down large empty tanks for storage. When the Moon has an established ISRU industry to utilize large quantities of lunar resources, it will be possible to manufacture a wide range of structural product and tankage to support the growth of the lunar bases and outposts. The lunar product range will expand from volatiles to glass and iron/steel casting, which are the next resources, going down the resources/energy list. The first large-scale steel products will be steel long stock (angle iron, I-beams, tubes, bars, rods, wire, etc.), because this will be the easiest energy wise, and it will expand to hot rolled plate for tankage and welded structures and/or cold rolled sheet steel. But these products require a significant capital equipment base and a large amount of energy to run.

If iron is available in the regolith near the lunar polar regions, then it may be possible to collect it electromagnetically and to use it to make small precision hardware if the required power is available, using 3D printing techniques, to produce iron and steel tools and fittings. More than likely, just as on Earth, larger manufacturing facilities will be strategically located near resources and markets. The important decisions for site locations are driven by many factors, starting with points of interest. Some will be based on science, while others will be based on transportation, location near resources, available power, and delivering product to the market, which are all major selection criteria, as well as cost drivers.

[12] See todaylibertyordeath.blogspot.com.

The power requirements for any lunar outpost will initially require surface-mounted solar panels for base power, but they will have to evolve to much higher power levels over time to support heavier activity. This may eventually require either a nuclear power plant, or if available, space solar power (SSP) systems orbiting the Moon.[13] Depending upon the necessary amount of industrial processing, the power levels will need to be adequate to the task, or they will limit the activity. Thus, there will be limited industrial activity at first, but the growth of outposts and bases will require parallel growth of power, resource utilization, and larger industrial applications to support growth. Figure 6 shows the relative energy requirements for processing various important ISRU materials.

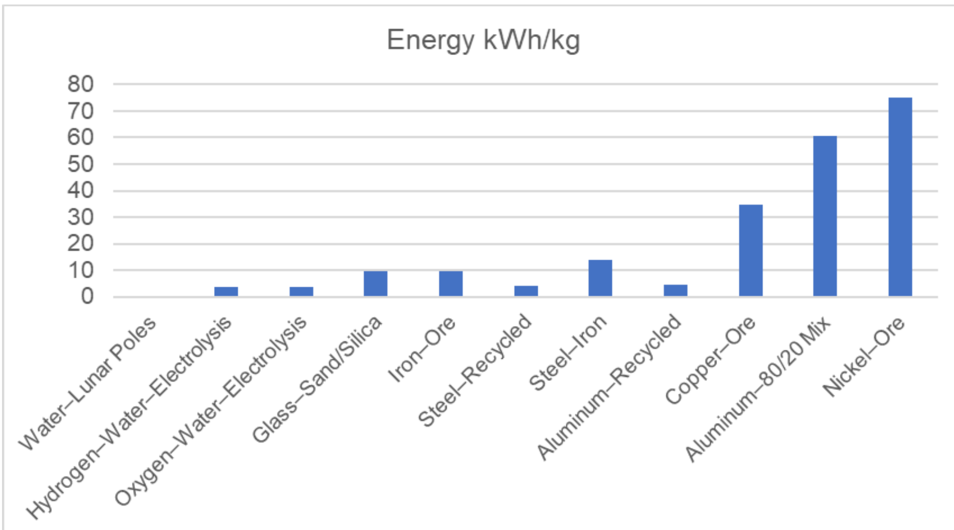

Figure 6. Energy requirements for processing ISRU materials.

Some ISRU materials will require a significant increase in available power before they can be economically produced on the Moon. Figure 7 shows this next group of higher energy materials.

[13] Source: https://en.wikipedia.org/wiki/Nuclear_power_in_space.

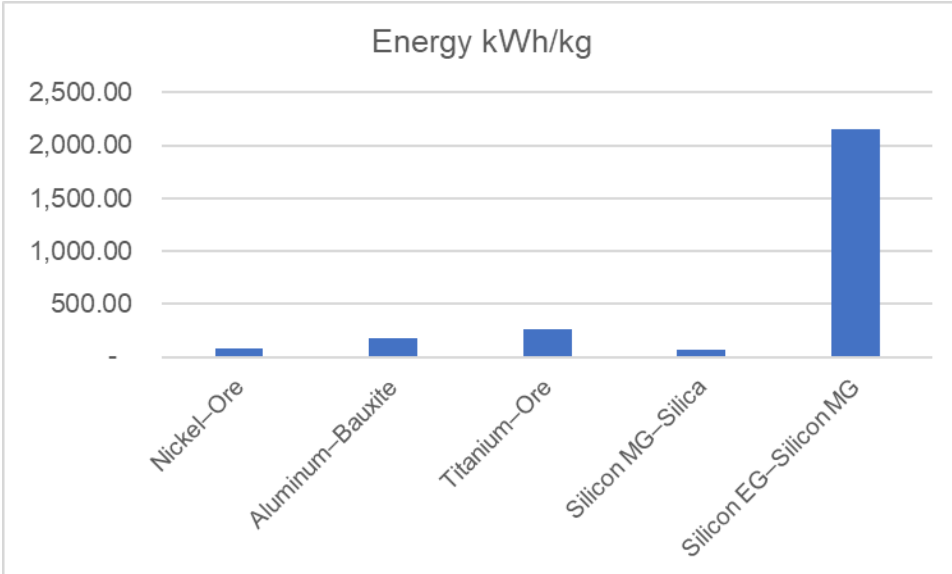

Figure 7. Energy requirements for processing higher energy ISRU materials.

The Moon is an ideal location for agricultural/farming research to learn how to grow food and support outposts off and away from Earth. This can be done most easily in sealed lava tube segments below the surface of the Moon. We know they exist, but they have never been explored. This is a separate topic, but it is a primary consideration for outpost site selection, because these tubes will need to be explored so we can utilize them for bio-regeneration, closed loop life support, and self-sufficiency.

Next let us consider the site selection process for outposts and bases. If scientific research is the only site selection activity, then lunar activity and growth will be slow and expensive. If, however, the rationale is expanded to include large-scale ISRU utilization and increased human presence, then industrial-size ISRU production along with bio-regeneration, growth of food, and other living necessities will be factors in site selection. Then this expanded scope of criteria will help to drive and fund the lunar growth activity. This in turn will energize the entire cis-lunar space economy with increased transport and trade activity, based on the availability of less expensive lunar resources.

A Basing Plan

John Mankins developed a reference plan called the Human and Robotic Modular Infrastructure/System (HARMONY).[14] Its objectives are to use robots and humans in a complementary fashion to achieve space exploration objectives. Robotic systems are used for the initial basing activity to set up human habitats and other lunar support systems, such as the communications and solar panels. This minimizes the risk to the humans, while maximizing the potential progress and reducing the cost.

This approach of paired efforts from robots and humans aligns with what we want to do. The first outposts will be at the poles, because that is where the water is. Water is the

[14] John C. Mankins, "Human and Robotic Modular Infrastructure/System (HARMONY)," Paper presented at the 51st International Astronautical Congress, October 26, 2000, Washington DC.

highest priority resource for making propellant and for life support. Oxygen from regolith with be the next most important ISRU for development. The basing plan suggests a four-phased approach:

Polar Outposts:

Phase 0	Precursor robotic missions (check out locations, prepare for outpost emplacement).
Phase 1	Lunar outpost emplacement (initially only one or two sites at or around poles).
Phase 2	Human lunar return preparations (in space infrastructure emplacement).
Phase 3	Human and robotic exploration with ISRU experiments (first human return for a hundred days).
Phase 4	ISRU emplacements and start production (start making and using ISRU – water, oxygen, hydrogen, iron, silica, other?).

In addition, there is a new teaming approach, in which NASA is asking for commercial partners to provide lower cost access to LEO. The new HARMONY plan recommends expanding this commercial approach even further to include industrial and science/exploration partners. In this new approach, commercial and industrial partners would help to accelerate and pay for the expansion into space, plus providing accelerated ISRU.

After establishing the first outpost(s) at the lunar poles, it will be of interest to reiterate the same phased approach to setting up outposts in other locations on the Moon, but with added phases as appropriate at each location to complete the exploration and characterization of the site. For example, if the site is near a large reservoir of regolith with a good concentration of iron, the site would be considered for a mine and/or quarry and an iron smelter and steel processing facility. Or, if the site is located near a skylight, it would be sensible to examine the interior of the lunar lava tube exposed by the skylight, and to evaluate its potential for a large human base. So, in that case, the phased approach to setting up the outpost might look like the one shown below.

Equatorial and Mid Latitude Outposts (Alternate Advanced Mission Option):

Phase 0	Precursor robotic missions.
Phase 1	Lunar outpost emplacement.
Phase 2	Human lunar return.
Phase 3	Human and robotic exploration with ISRU experiments.
Phase 4	ISRU emplacements and start of production.
Phase 5	Lunar lava tube robotic exploration.
Phase 6	Lunar lava tube human and robotic exploration and development.
Phase 7	Initial lava tube base.
Phase 8	Advanced human subsurface outpost and advanced bio research.

There needs to be a strong focus on how to use the lunar ISRU resources, and a start to preparations for industrial-level production. If we do not start using the resources, our efforts to go deeper into space will not materialize very quickly. The optimal situation for humanity is to learn to develop and use the lunar resources to maximize our potential for expansion into space. The basic and heavy industries will help to pay the way.

Heavy Industry–Capital Equipment

As we are doing basic ISRU experiments (Phase 3), we will need to start considering how to use the lunar resources and what will be required for ISRU (capital equipment) emplacements, to start production in Phase 4. In Phase 3, small laboratory-sized equipment will be necessary to make sure we understand the details of what is available and possible, and what the requirements will be for larger scale production. The capital equipment for Phase 4 will be custom designed for lunar operations: it will be designed, set up, and tested on Earth first, then disassembled in modular fashion and packaged for shipment to the Moon. Commercial partners will provide the design, set up, and test on Earth, and then they will make arrangements for lunar support for setup on the Moon with automated (tele-robotic) installations with Earth-based operators. A first estimate of the necessary capital equipment is as follows:

Capital Equipment, Iron and Steel Foundry

- Solar panels mounted on heliostat tracking systems to follow the sun during sun light operations (sunlight operations = fourteen days).[15]
- Solar reflectors mounted on heliostat tracking systems to follow the sun during sunlight operations.
- Electric arc furnace (1 ton capacity). Will weigh about 10-20 tons and require about 1-2 MWhe.

To produce about 1 ton of iron for casting:

- Preheat oven for iron ingots entering rolling mills, will use Heliostat Solar Reflectors, 2 MWh.
- Sintered regolith for oven enclosure. Not much electricity required, but a lot of heat.
- Rolling mill for long stock. Estimated to weigh about 20-40 tons, requires about 2-5 MWhe.
- Long stock includes angle iron, I-beams, bars, rods, and wire.
- Rolling mill for plate stock. Estimated to weigh about 20-40 tons, requires about 2-5 MWhe.
    - Plate stock is hot-rolled steel plate of various thicknesses.
- Rolling mill for sheet stock. Estimated to weigh about 20-40 tons, requires about 2-5 MWhe.
    - Sheet stock is cold-rolled steel plate of various thicknesses.
- Some of the weight may be reduced by using lunar resources, but there is no reduction in the electrical power requirement.

[15] See www.heliogen.com; www.lightmanufacturingsystems.com.

Capital Equipment, Glass Foundry:

- Solar panels mounted on heliostat tracking systems to follow the sun during sunlight operations.
- Solar reflectors mounted on heliostat tracking systems to follow the sun during sunlight operations.
- Furnace (1 ton capacity), with extrusion pour/casting capability, and preheat oven for glass melting and forming/blowing will use Heliostat Solar Reflectors, 1-2 MWh.
- Sintered regolith for oven enclosure. Not much electricity required, but a lot of heat.

Basic Support Industry and Services:

- Strip mining and refining of ores; iron, silica, alumina, etc.
- Machine shop for precision machining requirements.
- Welding shop for steel assemblies.
- 3D print shop:
    - Large to medium sized regolith sintered structures.
    - Small to medium sized metal precision parts.
    - Small sized plastics and other materials.

Aluminum smelting will come later, since it requires 6-10 times more electrical power than iron or steel, but it could use some of the same rolling mill systems as steel.

Electronics grade silicon will require even more energy to process, since growing silicon crystal is very heat intensive (20x more than aluminum).

Proposed Industrial Initiatives Plan

So, given what we know, it is proposed that along with a revised and current version of the HARMONY Basing Plan for setting up the first bases on the Moon, we will solicit industrial participation to create industries on the Moon, to help to support lunar development and growth. The first industries proposed are lunar volatiles from the lunar poles (water, oxygen, and hydrogen), and other undefined volatiles, to support fuel depots and life-support needs. Next would come the easier industries, glass and iron, as they require about the same relatively low energy levels to operate. More oxygen would be a byproduct of the iron foundry industry, and eventually the aluminum industry.

The following cost study for the initial iron and steel Industry on the lunar surface is a study model based on the HARMONY plan. It is not an alternate to the HARMONY plan, but it is an industrial initiative addendum to a HARMONY-like plan. It would require other industrial initiatives to be working parallel as well, such as the mining and refining industry, machine shop industry, welding industry, and glass industry. Each of these industries would be created and run by industrial partners as part of a larger scale initiative to develop the lunar resources and to support human expansion and settlement.

Table 5 is patterned after the HARMONY plan, running from Phase 0 through Phase 4. The robotic systems will be patterned after the NASA robonaut design,[16] and they will be tele-operated from Earth. The robonauts will be the onsite workers for the modular assembly of the iron and steel mill systems, and they will be mounted on R2 (electric) Jeep vehicles. The habitats shown here are Bigelow BE330-based designs, and they would need to be housed/protected in a regolith dome structure for radiation protection and thermal stability. It is anticipated that the outpost set up and foundry/steel mill set up will work in parallel and share some resources. A lot of the original HARMONY systems and their costs are not included, or are reduced, in this study because the industrial initiative would run parallel with or post HARMONY outpost set up. Some of the items excluded/reduced because they are not specific for this activity are:

SSP—Space Solar Power systems
EPS—Electronic Power Systems
Cryogenic Propellant Depot

The estimated costs for Phases 0, 1, 2, and 3 are as accurate and complete as can be determined today. However, they are estimates, and there are so many variables that when the actual program planning starts, these work sheets will need to be revised. One of the biggest variables is the market size and demand for steel. Steel is a primary structural material, and it will be required, just as it is here on Earth, in building larger structures. That variable will drive the production volume, furnace capacity, mass, and power requirements for the furnace and rolling mills. Although SSP and EPS units have been included, they may not be required in the phases identified initially, if at all. Phases 0, 1, 2, and 3 are precursor and preparation missions that set up for Phase 4, which is the start of industrial capacity emplacement. Phases 1-3 may be scaled back if there is less initial effort required. Phase 4 could be increased later as conditions require.

The most important result of this exercise is to provide an example and to start the dialogue about what would be required for industrial scale implanting on the lunar surface to start iron/steel ISRU processing. It will not take as long to amortize the costs when the industrial partners decide to get involved.

The post-Phase 4 exercise has even more uncertainty, but this too has some of the same unknowns as the other phases, and it is heavily dependent on how the market evolves. This part of the exercise is primarily a look into what is possible (Table 6).

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[16] Robonaut 2 From NASA: www.nasa.gov/mission_pages/station/main/robonaut.html; www.nasa.gov/pdf/464887main_Robonaut2_FactSheet.pdf.

Table 5. New HARMONY Revised Plan (2020), Part 1

PHASE 0 **Capital Equipment, Iron and Steel Foundry**	**Number Required**	**Mass lbs.**	**Additional Mass**	**Total Mass lbs.**	**Purchase Cost Each**	**Total Cost**	**Power Each kWh**	**Power Total kWh**	**Transport DV Cost $930 US**	**Comments**	
Solar panels (6) on each heliostat (150/6 lbs. = 25 lbs., on 833 assemblies + heliostat)	1,000	150	15,000	165,000	$2,000	$2,000,000	1	1,000	167,400,000	Electric	6 Panels per heliostat
Robonauts	4	330	2,000	3,320	$5,000,000	$20,000,000	-0.5	-2	4,947,600		
R2 (elect.) Jeep	4	4,000	15,000	31,000	$1,000,000	$4,000,000	-6.6	-26.4	42,780,000		
Robonaut garage, charge, repair, night retreat	1	16,000		16,000	$5,000,000	$5,000,000			14,880,000		
Remote control/communications system	1	2,000		2,000	$1,000,000	$1,000,000			1,860,000		
Mission operations	1				$10,000,000	$10,000,000			-		
				217,320		$42,000,000				**Total Cost Phase 0**	**$273,867,600**

PHASE 1 **Capital Equipment, Iron and Steel Foundry**	**Number Required**	**Mass lbs.**	**Additional Mass**	**Total Mass lbs.**	**Purchase Cost Each**	**Total Cost**	**Power Each kWh**	**Power Total kWh**	**Transport DV Cost $930 US**	**Comments**	
Solar panels (6) on each heliostat (150/6 lbs. = 25 lbs., on 833 assemblies + heliostat)	1,000	150	15,000	165,000	$2,000	$2,000,000	1	1,000	167,400,000	Electric	6 Panels per heliostat
Robonauts	6	330	2,000	3,980	$5,000,000	$30,000,000	-0.5	-3	5,561,400		
R2 (elect.) Jeep	4	4,000	15,000	31,000	$1,000,000	$4,000,000	-6.6	-26.4	42,780,000		
Robonaut garage, charge, repair, night retreat	1	16,000		16,000	$5,000,000	$5,000,000			14,880,000		
Remote control/communications system	1	2,000		2,000	$1,000,000	$1,000,000			1,860,000		
SSP units	3	6,600		19,800	$90,000,000	$270,000,000			18,414,000	To where?	
EPS units	3	4,400		13,200	$50,000,000	$150,000,000			12,276,000	To where?	
Mission operations	1.5				$20,000,00	$30,000,000			-		
				250,980		$492,000,000				**Total Cost Phase 1**	**$755,171,400**

PHASE 2 & 3 **Capital Equipment, Iron and Steel Foundry**	**Number Required**	**Mass lbs.**	**Additional Mass**	**Total Mass lbs.**	**Purchase Cost Each**	**Total Cost**	**Power Each kWh**	**Power Total kWh**	**Transport DV Cost $930 US**	**Comments**	
Solar panels (6) on each heliostat (150/6 lbs. = 25 lbs., on 833 assemblies + heliostat)	1,000	150	15,000	165,000	$2,000	$2,000,000	1	1,000	167,400,000	Electric	6 Panels per heliostat
Robonauts	6	330	2,000	3,980	$5,000,000	$30,000,000	-0.5	-3	5,561,400		
R2 (elect.) Jeep	4	4,000	15,000	31,000	$1,000,000	$4,000,000	-6.6	-26.4	42,780,000		
Robonaut garage, charge, repair, night retreat	1	16,000		16,000	$5,000,000	$5,000,000			14,880,000		
Remote control/communications system	1	2,000		2,000	$1,000,000	$1,000,000			1,860,000		
SSP units	3	6,600		19,800	$90,000,000	$270,000,000			9,900,000	LEO	
EPS units	3	4,400		13,200	$50,000,000	$150,000,000			6,600,000	LEO	
Cryogenic propellant depot	6	13,272		79,632		$-				Transport where?	
Bigelow habitat BE330 #1 + Regolith sintering robots	1	50,000	20,000	70,000	$50,000,000	$50,000,000			83,700,000		
Mission operations	1.5				$20,000,000	$30,000,000			-		
				400,612		$542,000,000				**Total Cost Phase 2 & 3**	**$874,681,400**

Table 5. New HARMONY Revised Plan (2020), Part 2

PHASE 4 **Capital Equipment, Iron and Steel Foundry**	**Number Required**	**Mass lbs.**	**Additional Mass**	**Total Mass lbs.**	**Purchase Cost Each**	**Total Cost**	**Power Each kWh**	**Power Total kWh**	**Transport DV Cost $930 US**	**Comments**	
Solar panels (6) on each heliostat (150/6 lbs. = 25 lbs., on 833 assemblies + heliostat)	5,000	150	25,000	750,000	$2,000	$10,000,000	1	5,000	720,750,000	Electric	6 Panels per heliostat
Solar reflectors on heliostats	2,000	67	210,000	134,000	$2,000	$4,000,000	1	2,000	319,920,000	Heat	
Electric arc furnace (1 ton capacity)	1	30,000	3,000	30,000	TBD		-2,000	-2,000	30,690,000		
To produce about 1 ton of iron for casting Ingots and/or SiO2–glass						$-					
Rolling mill ingot preheat oven (sintered regolith)	1	2,000		2,000	$10,000	$10,000	-2,000	-2,000	1,860,000	Heat	
Rolling mill for long stock (modular)	1	60,000		60,000	$1,000,000		-3,500	-3,500	55,800,000		
Long stock includes angle iron, I-beams, bars, rods, and wire.						$-					
Electrical interconnects system (harnesses)	TBD	25,000									
Remote control/communications system	1	2,000		2,000	$1,000,000	$1,000,000			1,860,000		
Robonauts	2	440		880	$5,000,000	$10,000,000			818,400		
R2 (elect.) Jeep	2	4,000		8,000	$1,000,000	$2,000,000	-6.6	-13.2	7,440,000		
Robonaut garage, charge, repair, night retreat	1	16,000		16,000	$5,000,000	$5,000,000			14,880,000		
Bigelow habitat BE330 #2 + Regolith sintering robots	1	50,000	20,000	70,000	$50,000,000	$50,000,000			83,700,000		
Additional facilities on Moon	TBD										
Additional equipment on Moon	TBD										
Mission operations	1.5				$20,000,000	$30,000,000			-		
Operations costs for 1 year on Earth											
Facilities on Earth											
Satellite costs											
Supplies for personnel on Moon											
Communications architecture											
Audio visual communications systems											
										Total Cost Phase 2 & 3	**$1,349,728,400**

POST PHASE 4 Capital Equipment, Iron and Steel Foundry	**Number Required**	**Mass lbs.**	**Additional Mass lbs.**	**Total Mass lbs.**	**Purchase Cost Each**	**Total Cost**	**Power Each kWh**	**Power Total kWh**	**Transport DV Cost $930 US**	**Comments**	
Solar panels (6) on each heliostat (150/6 lbs. = 25 lbs., on 833 assemblies + heliostat)	5,000	150		750,000	$2,000	$10,000,000	1	5,000	697,500,000	Electric	6 Panels per heliostat
Solar reflectors on heliostats	2,000	67		134,000	$2,000	$4,000,000	1	2,000	124,620,000	Heat	
Electric arc furnace (1 ton capacity)	1	30,000		30,000	TBD		-2,000	-2,000	27,900,000		
Rolling mill for plate stock (modular)	1	80,000		80,000	TBD		-4,000	-4,000	74,400,000		
Plate stock is hot rolled steel plate of various thicknesses.						$-					
Rolling mill for sheet stock (modular)	1	100,000		100,000	TBD		-5,000	-5,000	93,000,000		
Sheet stock is cold rolled steel plate of various thicknesses.						$-					
Mission operations	1.5				$20,000,000	$30,000,000			-		
Electrical interconnects system (harnesses)	TBD										
Remote control/ communications system	1	2,000		2,000	$1,000,000	$1,000,000					
										Total Cost Phase 4	**$1,062,420,000**

Table 6 gives a summary of the various phases of the lunar industrial ISRU facility emplacement for iron and steel is shown below. Note that the cost for emplacement at $500/lb. to LEO is in yellow highlight. The cost at $1,000/lb. to LEO is the next line, and the last lines sets out the costs if the price drops to $300/lb. (not likely). The top line is the original HARMONY plan for comparison.

Table 6. Phases of the Lunar Industrial ISRU Facility Emplacement for Iron and Steel

HARMONY Comparison	Phase 0 $ Million	Phase 1 $ Million	Phase 2 & 3 $ Million	Phase 4 $ Million	POST Phase 4 $ Million ISRU Only	POST Phase 4+ $ Million
HARMONY Costs (2000)	$640	$3,600	$11,800	$1,650		$970,001
New Plan Costs (2024) Steel Mill @$500/lb. to LEO (1.00)	$274	$755	$1,350	$1,350	$1,062	$-
New Plan Costs (2024) Steel Mill @$1010/lb. to LEO (2.02)	$553	$1,525	$2,726	$2,726	$2,146	
New Plan Costs (2030) Steel Mill @$300/lb. to LEO (.61)	$167	$461	$823	$823	$648	

Mission operations costs are included in the cost for lunar capital equipment emplacement. However, mission operations are a part of the ongoing program and operations costs, which are estimated at approximately $20 million per year. The cost of human presence on the moon is not addressed in this exercise beyond the two Bigelow BE330 habitats. Human operations will be treated as a separate accounting and estimating process. The initial set up and operation of the facility is intended to be tele-robotic and automated to a large extent.

Using the information from the above iron/steel ISRU facility implanting, we can deduce the following:

If launch costs are $500 to LEO, then the iron/steel implantation project cost would be $3.7 billion, and the cost would be amortized in 20.0 months, after producing 1,663 tons of steel (long stock).

If launch costs are $,1000 to LEO, then the iron/steel implantation project cost would be $7.5 billion, and the cost would be amortized in 40.5 months, after producing 3,360 tons of steel (long stock).

These estimates do not include shared cost by other partners in Phases 0 and 1, which could reduce costs, or synergistic influences from other industries and activities, which could share some of the same transportation and power services

Concluding Remarks

There needs to be a strong focus on how to use the lunar ISRU resources, and a start to preparations for industrial-level production. If we do not start using these resources, our efforts to go deeper into space will not materialize very quickly, if at all. Certainly, if there is no heavy lift capability, humanity will forever be mired in the expeditionary science only mode of space operations. This is not good enough!

The optimal situation for humanity is to learn to develop and use lunar resources to maximize our potential for expansion into space. And then, other near-Earth object resources, and the asteroids. The basic and heavy (resources) industries will help to pay the way and make it possible.

Once the first industrial (ISRU) facility is operating on the Moon, others will follow. It remains to be seen which ones will be first, and how big the operations will be. There are various predictions for how the Moon will be used in the future. There are the small lunar village scenarios (for only science) like the Antarctic analogue of 150 to 1,000 people, not much ISRU, and certainly not on an industrial scale.

There is a more aggressive vision of industrial ISRU that sees thousands of humans living and working in space, with an ongoing and expanding ISRU industry that expands throughout the solar system.

And then there is the (Gerard O'Neill/Jeff Bezos) vision of millions of people working in space and no heavy industry on Earth. The NSS vision is more like the last one.

If we are to become an interplanetary species, then ISRU on a large scale is required. We will need the heavy industrial activity to support our off-Earth existence, and it in turn will help to pay the way. We must not be timid about what we are to do. We must think like Gerard O'Neill, Elon Musk, and Jeff Bezos—bigger is better.

Comments About Assumptions

In preparing this study, many assumptions were necessary, and undoubtedly further study will show change and revisions to the original worksheets and ideas. Some of these assumptions are discussed below, and they will evolve further as a balanced mix of commercial, industrial, science, and exploration partnerships is established.

IT IS PARAMOUNT that the SpaceX SS/SHB becomes a reality, and it really does reduce cost per lb. to LEO. Also, that other competitive systems are designed and implemented in an ongoing process of improvement.

ΔV to LEO was used as a basis for costing ΔV in the cis-lunar space area. This assumes the cost for ΔV is a constant in this area, which may not be true.

Refueling depots in cis-lunar space will be required. An estimate for using StarShip to go to the Moon, land, and return to Earth, will require five to six tankers, or four to five depot rendezvous.

The ability to obtain fuel from lunar pole locations (not from Earth) for depots is assumed.

For Phases 0 and 1, two StarShips to the lunar surface will be required, thus, one LEO tanker and as many as four depot visits for fuel will be necessary, one depot in lunar orbit, one at EML1, and one in LEO on return.

Multiple heavy industries will be required, in some cases, to support each other, but this paper only focuses on the effort to establish a steel industry as an example.

The technology readiness of electric arc furnaces to make steel on Earth is TRL 9, but in a vacuum environment on the lunar surface, it may not even be TRL 8, and maybe as low as TRL 6. There will be very little carbon available on the Moon to use in industrial processes.

The technology readiness of steel-making on the Moon may not be TRL 9, as it is on Earth, but it may be TRL 6 or 7 (aka the ability to meet alloy and mechanical properties similar to those obtained on Earth).

The technology readiness of tele-robotic systems to perform the required work on the Moon has not been demonstrated, although it has been demonstrated on the ISS; thus, it may be TRL 6.

The operation and support of Bigelow BE330 habitats will be auxiliary to tele-robotic operations for human visitation, it may be part of the science, exploration, commercial, and industrial consortium, and thus it may be covered under a separate budget and accounting system to be used primarily for human visitation support.

Support industries and iron/steel works will be part of a larger new HARMONY-type plan to start with initial outposts, and then to spread and grow industrial capability and to initiate larger scale settlement and life support in conjunction with lunar exploration and scientific investigations.

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Editors' Notes: This technical article by Stevan Akerley is an outstanding example of quality research and analysis for a critically important Space development study. It meets the requirements for a master's level thesis. It sets out a plausible scenario for developing the Moon and beginning to move into Space, including costings. It should provide a foundation for further development work into Space settlement. Stevan Akerley is one of KSI's first academic scholars after Florida State licensing in 2019, and he may be the first scholar to complete a KSI Certificate Program. ***Gordon Arthur and Bob Krone*.**

About the Author: Stevan Akerley is a retired aerospace engineer from Pratt & Whitney, UTC, with forty years of manufacturing and engineering experience with automated N/C equipment and measurement sensor systems in manufacturing applications. He also has experience in precision manufacturing, machine measurement, CAD/CAM software development, quality assurance, and tool and equipment design. Stevan was involved in project and program management on multiple engine programs.

He holds an AA degree in liberal arts, a BS degree in industrial technology, and an MBA degree in Management Information Systems and International Business. He also holds a Computer Information Technology Certificate from Central Connecticut State University and he is currently serving as a Space Ambassador with the National Space Society.

Journal of Space Philosophy Board of Editors

Kepler Space Institute (KSI) is honored to have 40 of the world's Space community professionals as members of the Board of Editors for the *Journal of Space Philosophy* (JSP).

Dr. Elliott Maynard, our JSP Board of Editors colleague, has beautifully stated both the purpose and the style for our peer reviews:

> This is such a hi-caliber group of leading-edge thinkers and supercharged individuals, it should be natural for each of us to wish to provide a supportive and synergistic environment for the others. I have also learned always to have someone else proof read any material I write, as I have discovered that the brain tends not to "see" my own simple mistakes. Ergo, within the new Kepler context I feel editors should be there to support our writers in the most creative and positive ways possible. (email to Bob Krone, March 23, 2013)

The purposes of peer reviews of article submissions to the JSP are: (1) to determine the relevance to the Vision and Goals of KSI; (2) to help the author(s) to improve the article in substance and style or recommend references; and (3) to provide publication recommendations to the Editor-in-Chief.

****

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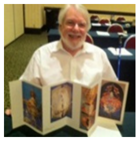
BOLTON, Jennifer, PhD, Co-Founder Virtual Space Orbiting Settlement VOSS. Veteran and molecular biologist, Space Pioneers Science Officer.

For Bio Info: Google Jennifer Bolton.

6. 

BURGESS, Lowry, Professor, Distinguished Fellow at the Studio for Creative Inquiry, Center for the Arts and Society, College of Fine Arts, Carnegie Mellon University.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 13.

7. 

CLEMENTS, Douglas H., MD, American Board of Ophthalmology, "Improving Human Vision for Space Exploration and Settlement".

Bio Info: Board Certified Ophthalmologist, USC Keck School of Medicine.

8. 

DOWNING, Lawrence G., DMin, Senior Pastor, Space Faith and Spirituality Pioneer, University Professor.

For Bio Info: See Issue 1, no. 1, Article 11.

9. 

FITZPATRICK, Susan Beaman, DBA, Vice Chairman, Oak Family Advisors, based in Chicago. International health expert specializing in health risk management. Susan's research interests include management capacity development and the implementation of complex innovations and programs.

10 

HAYUT-MAN, Yitzhaq (Isaac), PhD, Architect for the Universe, The Jerusalem Dome of the Rock as a memory site for theology, philosophy and humanity past, present and future.

For Bio Info: Google Yitzhaq Hayut-Man.

11. 

HOPKINS, Mark, Chairman of the Executive Committee, National Space Society (NSS), Space Economics. Important in founding of the L-5 Society and collaboration of the NSS with the KSI.

For Bio Info: www.nss.org/about/hopkins.html.

12. 

ISAACSON, Joel D., PhD, "Nature's Cosmic Intelligence," pioneer of RD Cellular Automata since the 1960s.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 7.

13. 

IVEY, Janet, Nashville TV treasure and a friend of KSI. Her *Janet's Planet* show is the recipient of 12 regional Emmys and five Gracie Allen Awards. She is an Ambassador of Buzz Aldrin's *Share Science Foundation*. A Google search will take you to delightful images and video clips of her teaching and entertaining children about Space.

14. 

KHOVANOVA-RUBICONDO, Kseniya, PhD, University of Chicago, Expert in public economics, innovation, policy and urban planning. Consultant to the Council of Europe and European Commission, proficient in six languages, Space International Economics.

For Bio Info: www.connect.tcp.org/profiles/profile.php?profileid=2296.

15. 

KIM, Kee Young, PhD, Republic of Korea Senior University Academician and Administrator. Former President, Kwang Woon University; former Dean of the School of Business and Provost, Yonsei University; currently the Chairman of the Board of the prestigious Samil Foundation, the oldest Korean institution to award and provide scholarships to high-performing scientists, artist and engineers.

16. 

KIKER, Edward, General Engineer, GS-13, Office of the Chief Scientist, US Army Space and Missile Defense Command/Army Forces Strategic Command, KSI Chief Scientist.

For Bio Info: www.indeed.com/r/Edward-Kiker/45bd40a86c090f07.

17. 

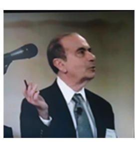
KRONE, Bob, PhD, JSP Editor-in-Chief, President, KSI, sponsor of this journal.

For Bio Info: www.bobkrone.com/node/103.

18. 

LIVINGSTON, David, PhD, Founder and host, *The Space Show*.

For Bio Info: www.thespaceshow.com.

19. 

MARZWELL, Neville, PhD, Space Solar Power and Robotics Scientist. Career at JPL as Manager for Advanced Concepts and Technology.

For Bio Info: www.spaceinvestment.com/lcr2_bios.html.

20. 

MATULA, Thomas L., PhD, Business and Management Professor, Lunar Commercial scholar.

For Bio Info: www.trident.edu/dr-thomas-matula.

21. 

MAYNARD, Elliott, PhD, Founder, ArcoCielos Research Center, Sedona Arizona, www.arcocielos.com.

For Bio Info: www.fasiwalkers.com/featured/ElliottMaynard.html.

22. 

MOOK, William, PE, Trained in aerospace engineering, 15 years in alternative energy, Space Commerce Technology.

For Bio Info: www.vimeo.com/user1527401.

23. 

OLSON, Thomas H., PhD, DBA, Professor of Clinical Management and Organization, USC Marshall School of Business, Los Angeles. Dr. Olson's specialty in research and consulting is on strategy, development, organization, and human capital. He has authored four books and 100 professional articles.

For Bio Info: www.marshall.usc.edu/faculty/directory/tholson.

24. 

PALMA, Bernardino, Historian, Portuguese Age of Discovery.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 8.

25. 

PEART, Kim, Co-Founder, Virtual Orbiting Space Settlement (VOSS). Artist, visionary, virtual worlds.

For Bio Info: www.independentaustralia.net/about/ia-contributors/kim-peart-bio/.

26. 

ROBINSON, George S., III, LLD, Space law pioneer and international space expert. Smithsonian Institute Legal Counsel.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 14.

27. 

SCHORER, Lonnie Jones, *Kids to Space* author and teacher. Architect, aviator.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 17.

28. 

SCHMEIKAL, Bernd, PhD, Retired freelancer in research and development, qualified in Sociology. He is a real maverick, still believing that social life can be based on openness and honesty. Member of the Trace Analysis Group of the UA1 Experiment at CERN. Institute for High Energy Physics (HEPhy) at the Austrian Academy of Science.

For Bio Info: See Issue 9, no. 1 (Spring 2020), Letters to the Editor.

29.

SCHRUNK, David, MD, Aerospace engineer, Founder, Quality Laws Institute, KSI Faculty.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 18.

30.

SCHWAB, Martin, PhD, International Space author, KSI Faculty, Aerospace Technology Working Group.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 21.

31.

SCOTT, Winston E., American Astronaut, Vice President for Development, Florida Institute of Technology.

For Bio Info: www.en.wikipedia.org/wiki/Winston_E.Scott.

32.

STEPHANOU, Stephen E., PhD, Emeritus Professor of Systems Technology, USC, Los Angeles.

For Bio Info: See Issue 2, no. 2 (Fall 2013), Article 26.

33.

TANG, Terry, PhD, Kepler Space Institute Director of Research.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 24.

34.

THORBURN, Stephanie Lynne, Author, Astrosociology.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 12.

35.

WERBOS, Paul, PhD, US National Science Foundation, Space scholar.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 19.

36.

WHITE, Frank, MSc, Founder, The Overview Effect Institute.

For Bio Info: See Issue 1, no. 1 (Fall 2012), Article 9.

37.

WILKINS, John, PhD, Professor of Space Settlements.

38. 

WOLFE, Steven, Space advocate and author of the 2013 Space novel, *The Obligation.*

For Bio Info: See Issue 2 no. 2 (Fall 2013), Article 26.

39. 

YACOUB, Ignatius, PhD, Founder and first Dean of the School of Business and Management, La Sierra University, Riverside, CA. Currently Professor of Graduate Studies, Loma Linda University School of Social Work and Social Ecology, Loma Linda, CA.

40. 

ZUBRIN, Robert, PhD, President, Mars Society.

For Bio Info: www.en.wikipedia.org/wiki/Robert_Zubrin.

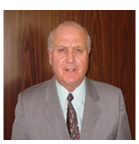
In Memoriam

BEN-JACOB, Eshel, PhD, Former President of Israel Physical Society; Founder Science of Bacterial Intelligence. Tel Aviv University. We grieve the passing of Dr. Ben-Jacob in 2015.

For Bio Info: Google Eshel Ben-Jacob.

MITCHELL, Edgar Dean, ScD, Captain, US Navy (Ret), Apollo 14 Astronaut, sixth person to walk on the Moon, Founder Institute of Noetic Sciences. We grieve Edgar Mitchell's passing in 2016.

For Bio Info: Google Edgar Mitchell.



O'DONNELL, Declan J., JD, Space law attorney, Fifty publications in Space Law and Policy, Publisher, Space Governance Journal, President, United Societies in Space, Inc. We grieve Declan's passing in 2015.

"The greatest use of a life is to spend it for something positive that outlasts it." Dr. Max T. Krone, Dean, Institute of the Arts, University of Southern California and Founder, Idyllwild School of Music and the Arts, 1950.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