The Journal of Astrosociology

Volume 2

Astrosociology Research Institute

THE JOURNAL OF ASTROSOCIOLOGY

VOLUME 2

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PUBLISHER'S NOTICE

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THE JOURNAL OF ASTROSOCIOLOGY

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Introduction

Welcome to volume two of the *Journal of Astrosociology*! Volume two represents our continued effort to publish astrosociological based manuscripts that cover a wide range of social science issues that deal with the two-way relationship between humanity and outer space. Volume two offers a wide spectrum of fascinating articles drawn from a variety of disciplines, including a book review of the "Palgrave Handbook of Society, Culture and Outer Space", which covers many astrosociological topics. I hope that you find volume two a great, thought-provoking read.

In 2014, I founded the *Journal of Astrosociology* at the Astrosociology Research Institute. As Editor-in-Chief, I am proud to see the journal grow and succeed to advance astrosociological thinking about space and society, but I am just as proud to turn over the Editor-in-Chief duties to Professor Michael Dodge from the University of North Dakota's Space Studies program. Professor Dodge will begin his duties with volume three of the journal as I step away to pursue new adventures. I hope you, the reader, will continue to utilize the journal for research, knowledge, or to acquire a different perspective about how space affects society and society affects space. This interdependency has always peaked my intellectual curiosity and I have spent over ten years helping to define and refine the field of astrosociology with my colleagues at the Astrosociology Research Institute. Thus, I look forward to future volumes of the journal and the new astrosociological research that it will produce.

I wish Professor Dodge and my colleagues at the Astrosociology Research Institute the best as I prepare to leave the institute at the end of the year. Thank you all for supporting the journal, the Astrosociology Research Institute, and the field of astrosociology.

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Volume two of *The Journal of Astrosociology* consists of six thought provoking articles and one book review. The first article entitled "Exploring the Inspirational Effect of a National Space Program: The Effect of Nationality on Feelings Towards the Ability to Get to Mars" is written by Dr. Ashley Chandler Karp and Dr. Alan Steinberg. The article explores initial research into the measurable effects of inspiration influencing people's perceptions of getting humans to Mars. As Dr. Karp and Dr. Steinberg state in the article's abstract:

> While there are many claims about the inspirational effect of space on young people, there is rarely measurable evidence to support them. This study attempts to identify the potential inspirational effect that a space program has through an examination of young people's beliefs in mankind's ability to send humans to Mars. The data suggest that there may be an inspirational or imaginative effect whereby the status of a country's space program may influence both an individual's feelings toward the ability to get to Mars as well as the lens through which the challenge to reach Mars is viewed. The article is also intended to be a catalyst for discussion and further studies on this topic.

The second article entitled "Criteria for Sustainability in the Orbital Environment" is written by Nathanael McIntyre. The article presents studies and offers solutions to the orbital debris issue that is becoming a growing concern in order to access and utilize space in the future. As the author's abstract states:

> Space debris continues to be a growing problem that affects a wide variety of stakeholders in the space environment. For example, the cupola on the International Space Station recently suffered damage after being hit by a small piece of debris smaller than a millimeter (Griggs, 2016). Although several solutions have been proposed, progress on the policy front remains slow. Understanding the interests of the myriad stakeholders affected by the problem and developing criteria to evaluate workability are crucial first steps that need to be taken before any proposed solution can be implemented. The debris issue has been characterized as a "tragedy of the commons," a concept first popularized by ecologist Garrett Hardin (1968) to describe common-pool resource (CPR) problems. These are problems in which multiple stakeholders rely on a resource, but none own it or are in charge of maintaining it for future use, leading to ruin for all. Later work by Elinor Ostrom (1990) critiqued Hardin's theory that privatization or government takeover were the only possible solutions to CPR problems, finding numerous real-world examples of resource appropriators, local officials, and other stakeholders successfully working together to manage CPRs. However, more recent scholarship has argued that Ostrom's framework may not translate directly to every CPR management issue, particularly when looking at global commons such as the oceans, the atmosphere, and outer space, due to issues of size and scale. Still, as the Secure World Foundation's Brian Weeden and Tiffany Chow (2012), and the Naval War College's Joan Johnson-Freese (2012) have noted, Ostrom's framework seems to provide a solid foundation for addressing orbital debris and wider questions of space governance, although it is in need of modification. Likewise, work by Paul Stern of the National Research Council concludes that Ostrom's framework can be useful for governing both the global commons and the risks of emerging technologies with the addition of further principles. Building on the aforementioned research, this article expands on the efforts to adapt Ostrom's framework and principles to the issues of space debris and space governance. It surveys the approaches used in the management of comparable global commons—including the atmosphere, the Antarctic, the oceans, the emerging commons of the Internet, and existing efforts regarding the orbital environment—and summarizes the lessons they can provide for the debris issue. It also seeks to fully elucidate the interests of each stakeholder group, from established space powers to developing countries, businesses, and the global public in order to develop a set of evaluative criteria that any solution must meet in order to have a chance at both policy effectiveness and political adoption. Finally, this article applies these criteria to a sample set of proposed solutions to the orbital debris problem in order to illustrate their practical utility.

Written by Gordon Gartrelle, his article is entitled "Digging Up the Cosmos: Is Asteroid Mining Economically Feasible?" The article explores asteroid mining and offers an economic analysis to provide an answer to the question of whether space resources are economically feasible to extract. As the abstract states:

> Asteroid mining has been proposed as a means of developing new supplies of raw materials for use on Earth and in space related endeavors. Several prominent business leaders including Larry Page and Sir Richard Branson view asteroid mining as a viable lucrative long-term business investment. Given the vast amount of capital

required and the numerous risks of any space related venture, how economically viable is asteroid mining? The purpose of this article is to understand whether a compelling business case for asteroid mining exists and, if so, to determine the potential timeframe until an asteroid mining venture can become profitable. This author reviews and analyzes the current literature on the topic utilizing several types of sources including public filings of named asteroid mining ventures, articles from mainstream business publications, and academic works concerned with the development and evaluation of profitable business cases. In doing so, a key component of this study involves analyzing the business cases of several terrestrial mining operations in extreme environments and compares them to potential asteroid mining scenarios. The findings of the research indicate the business case for asteroid mining is potentially financially attractive though it contains several major exposures and risks that are difficult to quantify. This suggests asteroid mining may not be viably profitable for several decades. Several recommendations are offered to improve the business case in order to make it more worthwhile in a shorter timeframe.

Dr. P.A. Hancock's article entitled "On Bored to Mars" offers an analysis of boredom as applied to future human spaceflight to Mars. As his abstract states:

> The next great exploratory step in the story of our species will come to fruition on the day that one representative of humankind first physically steps onto the red planet. In theory, the majority of physical barriers that stand between this watershed event and us are soluble. Even our contemporary technologies have placed robotic explorers on Mars; and thus, in principle, there are few prospective showstoppers that would absolutely defeat a human mission. Here, such physical limitations that threaten mission success are not featured. Rather, the emphasis is on the psychological constraints that must be overcome if our failure-intolerant society is to sufficiently support this vital, species-altering enterprise.

Dr. P.J. Blount and Jake Fussell co-author the article entitled "The Space Age Narrative as Reflected in Southern Music." The article explores the influences the space age had on southern music. As their abstract states:

> This article briefly explores the notion of the Space Age as a historical and cultural construct in the Southeastern United States through an analysis of Southern music across a range of time periods and genres. It argues that the Southern culture reflects a complex understanding of the space age as a technological and political phenomenon with both global and local impacts.

In the final article of volume two, Andrew Fergus Wilson analyzes the intersection of outer space and alternative religion and conspiracy theories in the article titled "Postcards from the Cosmos: Cosmic Space in Alternative Religion and Conspiracy Theories." As his abstract states:

> If conspiracy theory is the narration of fears of existential dread, of a potentially apocalyptical plot against "us," then we can understand alien conspiracies as a dread of the coming of "cosmological humanity" and the end of "geostationary man." In escaping gravity's hold a terminal velocity is achieved by a species ready to mythologize, even sacralize, its achievements, and to enchant the heavens once again in terms more suited to the technological age. Virgiliu Pop's astrosociology

will provide a means for framing the uniqueness of post-Gagarin conspiracist spiritualities within the particular religious cultures of cosmic humanity while Raymond Williams' concept of "structures of feeling" will be drawn upon to understand the cultural significance of these spiritualities.

Finally, we finish volume two with a book review from Dr. Kathleen D. Toerpe of "The Palgrave Handbook of Society, Culture and Outer Space", edited by Professors Peter Dickens and James Ormrod. Dr. Toerpe provides a great summary and her views on the work Dr. Dickens and Dr. Ormrod has put together in their intriguing anthology of space issues.

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As Editor-in-Chief of *The Journal of Astrosociology*, I wish to personally thank the Executive and Assistant Editors, the Editorial Board, and authors for contributing their time and effort in support of the journal. I also personally thank Dr. Pass for his vision in developing and growing the field of astrosociology. They have all made this endeavor a success. I now appeal to the reader to contribute to the cause this journal sets forth, either through submission of manuscripts, reading about and supporting astrosociology, or passing along our contributions to the physical and social sciences to others.

Thank you for your continued support.

Christopher M. Hearsey, M.S., J.D.

Editor-in-Chief

The Journal of Astrosociology

Welcome to the Second Volume of the Journal of Astrosociology

Unquestionably, 2016 was a good year for the Astrosociology Research Institute (ARI), and this second volume continues excellent developmental progress of the field in 2017. As the CEO of ARI and founder of astrosociology, I am heartened by the progress being made. This second volume of our flagship journal is a palpable indicator of that. As one of the executive editors, I have seen firsthand how the construction of this second volume of the journal validates the continuing commitment to develop astrosociology as an academic field from within the organization, but perhaps more importantly, from outside it as well. This volume includes a variety of astrosociological topics from diverse authors.

As a reminder, astrosociology is defined as the study of social, cultural, and behavioral patterns related to outer space (i.e., astrosocial phenomena). Why is the development of astrosociology important at this stage of the space age, which is now interwoven with the NewSpace movement? As Albert A. Harrison has taught us, human beings and thus the human dimension matters. Moreover, space exploration increasingly matters. Combined, government space agencies and commercial space companies have ramped up the progress of space exploration, potential extraction scenarios, and settlement.

This issue of the JOA demonstrates the importance of astrosociological issues, not only in the diversity of the topics covered such as the feasibility of asteroid mining and coping with space junk, but also in terms of the fact that a growing number of scientists and scholars are concluding that a specific field dedicated to a social-scientific approach to space issues mandates the existence of a centralized approach. In the past, especially before the turn of the previous century, the prevailing notion was that isolated researchers in disciplines with rigid boundaries represented an adequate approach to cover what we now call astrosociological topics. Predictably, in sociology, for example, relatively little work was accomplished compared to mainstays such as criminology and medical sociology. Important space-related scholarship tended to be only narrowly shared and thus progress remained comparatively slow. Astrosociology exists to provide a community in which interested parties can share their work, readily understand what is available to them, and contribute to building an important knowledge base. The growth of cooperation from those in various disciplines and fields has helped to accelerate progress, and that is why astrosociology takes multidisciplinary and interdisciplinary approaches today, though much still needs to be done.

Thus, why astrosociology and the JOA matter is an important concept to consider. Without astrosociology, there is no field that coalesces social-science-oriented space related topics into a single field. This journal – and the *Astrosociological Insights* newsletter (discussed below) – provide a way to organize such matters in an increasingly recognizable place. As more astrosociologists join us in our effort to develop astrosociology specifically, the literature will blossom for the benefit of all those who conduct research, provide educational benefits, and work in space-related occupations.

As astrosociology continues to develop, two objectives exist aimed to grow the astrosociology community. First, drawing in more social scientists and humanists is vital because the history of their participation demonstrates a consistent apathy toward astrosocial phenomena, the very reason why astrosociology was founded. As related earlier, however, this is slowly changing for the better as our efforts, and those of others, continue. Second, collaborating with physical and natural scientists working on space issues is important because formal collaboration can result in insights that neither side can discover on its own. ARI's mission is to continue building an astrosociology community in which space-related education and research are shared across disciplines in both branches of science.

It is important to publish this volume to make astrosociological research findings available for interested individuals and policymakers. It demonstrates the relevancy of a social science oriented approach to the study of space issues that focuses on humanity and its social institutions and culture, both on Earth and in the space ecosystems to follow beyond the ISS. A related goal is to inspire all types of scientists and scholars interested in space issues as they relate to humanity (i.e., astrosocial phenomena) so that they consider contributing to astrosociology's development in the future. In the future, we anticipate that inspired individuals will offer manuscripts for articles in Volume 3 and beyond.

I also encourage readers to check out the newsletter issues, the latter two of which (1) examined the impact of Star Trek during the year of its fiftieth anniversary and (2) explored the issues relevant to the topic of space settlements. All issues of the *Astrosociological Insights* newsletter are available at no cost in the ARI Virtual Library at the following URL:

www.astrosociology.org/vlibrary.html#VL_Newsletter.

Additionally, there are other astrosociology references on the Virtual Library page at:

www.*Astrosociology.org*,

which should be of interest to anyone curious about the impact of outer space on culture, society and humanity as a whole.

Lastly, I wish to acknowledge the hard work by ARI officers and editors from around the world that include Kathleen D. Toerpe and Renato Rivera Rusca, and especially Christopher M. Hearsey, our Editor-in-Chief. See our *Journal* page for a listing of the other vital contributors at:

www.astrosociology.org/JOA.html.

It takes a lot of work to bring such an impressive volume together. A link to the first volume is also available there.

So, welcome to the second volume of the JOA. Enjoy!

Jim Pass, Ph.D.

Chief Executive Officer

Astrosociology Research Institute

ARTICLES

Exploring the Inspirational Effect of a National Space Program: The Effect of Nationality on Feelings toward the Ability to Get to Mars

Ashley Chandler Karp, Ph.D.*
Jet Propulsion Laboratory, California Institute of Technology

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ABSTRACT - While there are many claims about the inspirational effect of space on young people, there is rarely measurable evidence to support them. This study attempts to identify the potential inspirational effect that a space program has through an examination of young people's beliefs in mankind's ability to send humans to Mars. The data suggest that there may be an inspirational or imaginative effect whereby the status of a country's space program may influence both an individual's feelings toward the ability to get to Mars as well as the lens through which the challenge to reach Mars is viewed. The article is also intended to be a catalyst for discussion and further studies on this topic.

I. Introduction

inspire: to fill (someone) with the urge or ability to do or feel something, especially to do something creative.[1]

Proponents of space exploration often talk about the inspirational value of space exploration, especially in regards to inspiring future generations. However, the concept is often nebulous and difficult to measure. Thus far, attempts focus on how space exploration influences other things, or how other things influence space exploration. For example, history suggests that space science has influenced science fiction and that science fiction has in turn influenced space science. However, we still do not know if space exploration actually has an inspirational effect on young people in any measurable way.

To date, the evidence of this inspiration is based on anecdotal and indirect relationships between science and the arts. However, a 2009 survey of researchers who had published in *Nature* revealed that while ninety percent of them believed that manned space exploration inspires younger generations to study science, only half of the respondents said they were in fact inspired by the Apollo program, which was arguably the most awe-inspiring of all space feats up to this point (Monastersky, 2009). This leads us to wonder, what do we mean when we say "space is

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[1] "inspire," English Oxford Living Dictionary, available from https://en.oxforddictionaries.com/definition/inspire.

inspirational”? It leads to an interesting question: are we putting too much (or conversely not enough) weight into the inspirational value of the space enterprise?

Such questions are too broad to attempt to answer given the current void of research into the inspirational value of space exploration. However, this study attempts to provide some insight into the larger discussion by seeking to understand how the capabilities of a nation’s space program can influence the beliefs and attitudes of young people from that country. Not only will this allow for a better understanding of how space exploration can impact the imagination of young people, but also to see if there is indeed a measurable degree of nationalism and national pride associated with differing opinions. This study seeks to start off this discussion by focusing on two aspects: 1) Does having a national space program provide a measurable inspirational effect? 2) What impact, if any, does stagnation within a space program have on this inspirational effect?

a. Inspirational Value of Space Exploration

The night sky has served as a source of multidisciplinary inspiration (Moore, Richman & Chamberlain, 2011), but what exactly does it mean when it is said that stars are inspiring? When someone references the “inspirational value of space,” they could be referring to any number of elements, but for this study the focus will be on a specific definition of inspiration: “the urge or ability to achieve.” This conceptualization allows for claims that any particular thing may in fact be the inspiration for something that comes after it. This fits with the popular usage of the inspirational value of space. For example, when an astronaut and a congressman joined forces to champion our national space program they wrote, “Space exploration is remarkably compelling for most Americans, a challenging pursuit that distinguishes the United States as a global leader, while ensuring a steady stream of innovative technologies that strengthen the economy and, just as importantly, inspiring our youth to dream big” (Collins & Lampson, 2013). The implication here is that scientific success leads young people to believe in their ability to achieve.

Another way to look at inspiration in regard to space is the relationship between space science and science fiction. Here, history suggests a strongly influential relationship where space science achievements inspired science fiction writers, which in turn inspired space exploration technologists, which in turn inspired another generation of science fiction writers, who again inspired advances in technology. This self-sustaining, cyclical history can be traced back for hundreds of years whereby science has fueled imagination and the resulting fiction has inspired scientific work (Winter, 1983). An early example is that after Galileo Galilei showed the world that there were planets other than our own, public interest in stories of space travel increased (McCurdy, 1997). Meanwhile, Robert H. Goddard, creator of the liquid bipropellant rocket, is said to have been inspired by science fiction stories, including H.G. Wells’ “War of the Worlds” (Michaud, 1986). As science advanced, so did the public’s interest in science fiction (McCurdy, 1997; Michaud, 1986). Fiction about space travel then in turn became an outlet for advocating the science of space (McCurdy, 1997). The interplay between these two realms is quite close as advocates of space exploration often used science fiction as a medium for expressing their interests and beliefs for the future (Bainbridge, 1983; Michaud, 1986; Winter, 1983). This implies that as our ability for space exploration continues to advance, so too does our imagination and the strength in our beliefs for what humankind is capable of achieving next.

Space-related events themselves have also inspired artists. Connections have been suggested from scientific invention, such as the depiction of telescopes in Brueghel’s paintings created just after the invention's unveiling in 1608 (Molaro & Selvelli, 2011) as well as from astronomical phenomena itself, as is suggested by the statistical analysis of medieval and renaissance art (Incerti, Bonoli & Polcaro, 2011). Art created from this inspiration reaches a broader swath of people and thus can serve to inspire those who are not typically exposed to space. In the same way that science fiction has been shown to inspire scientists, space art provides images that work in tandem with words to inspire new scientific ideas.

The outcome in all cases is that space exploration has the power to inspire future activity, and as history shows, specifically future space exploration. When thinking about the space program, success in one endeavor could be inspiration for taking the next step. For example, putting a satellite into space inspires putting humans into orbit, achieving orbit inspires putting humans on the moon, and so forth. This may seem to be a rather simplistic and mechanical view of inspiration, but previous successes in space did seem to provide the inspiration needed for people to push for more space exploration (Michaud, 1986) and it is the one chosen for use in this pioneering study. Moreover, the only works on the inspirational value of space seems to fit this systematic approach. In his book, *Space and the American Imagination,* Howard McCurdy argues, "Since its beginnings, the U.S. space program has been motivated by a highly romantic dream" (1997, 1). Successes such as the Apollo program became an immense source of American pride (Bainbridge, 1976), fueling the incremental steps toward more complex goals in space exploration. This straightforward approach allows for clear testing of specific hypotheses, and there has yet to be a better view put forward and tested in this regard.

b. <u>Corollaries to the Inspirational Value of Space</u>

It is also important to note that space endeavors and space history have been generally nationalistic in nature. Space activities have been linked to aspects of soft power and national prestige since their beginnings (Logsdon, 2008). Moreover, it seems to be the inspirational aspects of spaceflight itself that explain why it has a deep-seated nationalistic identity (Krige, 2009). This implies that people living in various countries would have differing views and levels of inspiration. For example, we would expect people from a country with a strong, successful space program to be exposed to more information about space and thus have more opportunity to be inspired by it than people from a country without a space program at all.

There may be speculation about how the high degree of international cooperation currently being presented within space projects might impact this theory. However, previous research has shown that there is a both a historical and media focus on the country that spearheads the project. For example, one of the first scientific experiments conducted on the moon by Neil Armstrong and Buzz Aldrin during the Apollo 11 mission was designed by a Swiss scientist and funded by the Swiss National Science Foundation. However, despite NASA's commitment to international cooperation, a U.S. flag was placed on the moon, as the moon landing was an American project (Krige, 2009). Moreover, seemingly cooperative international programs, such as the International Geophysical Year, have been argued to be a "collection of national programs" working independently toward a mutual goal rather than actual "international scientific cooperation" (Furtkin, 1965).

Scientific setback may also influence our beliefs. Across a series of polls asking if the government should fund human trips to the Moon, it is in July of 1967, a few months after the Apollo 1 accident, which killed three astronauts, in which the lowest percentage of Americans showed support (Launius, 2003). Similarly, after the explosion of the Space Shuttle *Challenger*, the vast majority of the American public felt that this was a setback for the space program, despite an increase in support for more funding for the space program (Miller, 1987). Space experts themselves are also subject to similar despair. Reflecting on unmet goals for the space program of the past, James Van Allen described them as “more like delusions in today’s reality” (Van Allen, 2004). These downturns in opinion show that perceived setbacks in space operations may inhibit a national space program’s ability to inspire.

Taken together, all of these factors suggest that a national space program may indeed have the ability to inspire the citizenry. Moreover, the relative success of a nation’s space program should lead to people from that country being inspired more than others. At a minimum, this should lead to increased belief in their country’s ability to succeed at future space exploration. This is particularly driven by the idea that technological success begets future technological development. However, it is also possible that scientific setbacks may have a negative impact on inspiration. These are the theories that this study seeks to explore though the framework of a manned mission to Mars.

c. <u>Inspiration and Reaching Mars</u>

A human mission to Mars has recently been suggested as being feasible as early as the 2030’s (Price, et al 2015). Price suggests that a manned mission to Mars orbit is feasible as soon as 2033 within the current funding profile of NASA (assuming adjustment for inflation). In response to this suggestion, over a hundred young people were asked questions related to this mission, its feasibility and challenges. The survey targeted the motivation for going to Mars, if they thought “we” as a society were ready to go and asked to identify major challenges. The idea is relatively straightforward: more inspired young people should have more positive attitudes toward the feasibility of this manned Mars mission. The following hypotheses explore this theory and the correlates expressed above.

H1: Respondents from countries with more highly developed space programs are more optimistic about sending people to Mars.

The literature on space exploration and inspiration would lead us to believe that most countries do not attempt space endeavors in a vacuum. Despite the fact that international cooperation is common with many space activities, people living within a given country likely focus on their nation’s accomplishments based upon both what that country has staked claim to and the independent technical abilities their country’s space program possess. Therefore, being from a country that has a space program should lead to young people being more optimistic about sending humans to Mars due to the space program’s ability to inspire such confidence.

H2: Respondents from countries with recently stagnated space programs are less optimistic about sending people to Mars.

Recognizing that life is not as simple as hypothesis 1 might suggest, hypothesis 2 provides for an exploration of the important corollary that just as success can lead to inspiration, failure may have an opposite effect. Moreover, success and failure are due to perceptions and can be influenced by money and politics as easily as by technological aspects. Due to this relationship, we hypothesize that a stagnated manned space program, such as what has happened recently in the United States, will have a negative effect on inspiration. Therefore, we believe that the United States in particular will not fit the general model that proposes that more developed space programs are better able to inspire.[2]

H3: Respondents from countries with more highly developed space programs are less likely to see technology as the barrier to sending people to mars.

Given that the literature suggests that technology and success have a positive impact on inspiration and thus we believe in the optimism of a Mars mission, it is important to dissect the opinion of the uninspired. As the literature suggests that technology begets technology, respondents from countries with a more highly developed space program should be less likely to see technology as a barrier. Instead, those respondents may see other factors, such as money and politics, as the barrier. For example, in the United States, the political and ideological battles may be an offset of the technological capabilities and therefore may lead to young people from the United States being less optimistic about sending humans to mars.

II. Data & Methods

Measuring inspiration is a challenging task. While you can ask someone if something inspired them or what inspires them, it is difficult to know if these things actually provided the definitional characteristics: to provide an urge or ability to do or feel something. In the *Nature* survey, respondents were asked a rather leading question, “Did the Apollo missions inspire you in any way to become a scientist?” It’s easy to answer “sure” or “yes” to such a leading question and two of the four answer choices were a variation of “yes.” Given that, randomly assigning respondents to these four choices would have led to a similar finding. Moreover, a scientist may feel as if Apollo should have inspired them, and thus agree that they were, even if they are only able to attribute a small bit of inspiration to it. The existence of this desirability bias is further emphasized by the fact that so many of these scientists believed that space was inspiring younger generations, because in their minds it *should*.

This study seeks to measure inspiration in a different way, not directly asking, but instead inferring. This methodology avoids the use of leading questions about inspiration or issues of desirability biases. The key question of interest for this study is simply “Do you think we will be ready to send humans to Mars by 2033?”[3] At first glance, this simple opinion-based question does not seem to measure inspiration, but inspiration is more than just about doing something, it is also an emotional response. We assume that a person who says “yes,” therefore believes in the ability for such an event to happen; they feel we as a society have the ability to do it.

[2] While we believe that other countries could be just as susceptible to this negative effect, no other country has recently experienced space setbacks to the same degree as the perception that came with the ending of the Space Shuttle program.

[3] This date as stated before is based on a recent scientific paper that suggests society as a whole will be through the actions of NASA (Price, et al, 2015).

The data for this study come from a sample of 108 respondents conducted via the Internet as part of a larger project exploring the opinions of young space-engaged individuals. Potential respondents were solicited through email and social media, targeting those who had already expressed an interest in space. Respondents are also asked about their nationality, in order to know if they are from a spacefaring country. Each country is coded based upon the technical capabilities of that nation's space program as: no space program, the ability for unmanned launches, or the ability for manned launches.[4] Respondents were classified into these three groups based upon their nationality.

The first is the group from countries with national capability to send humans into space: The United States, Russia, and China. The United States is also considered alone in one instance to evaluate the potential effect of a stagnated or regressed space program.[5] The second group includes countries with launch capabilities to independently deliver cargo to space. This includes respondents from European Space Agency (ESA) member states, India, and Iran. The final group includes those countries without independent national capability to reach space. In the case of this study, this includes: Argentina, Australia, Bolivia, Croatia, Jamaica, Lebanon, Mexico, New Zealand, Nigeria, Slovenia, South Korea, and Thailand.[6]

The metric of inspiration is determined by the average score of respondents from each of the three categories in regards to the question, "Do you think we will be ready to send humans to Mars 2033?" An affirmative answer is coded as a 1 and a negative answer is coded 0. To test hypothesis 1, the average score of respondents from each of the space program categories is examined. To test hypothesis 2, the average score of respondents from the United States is considered separately from other countries in the human space launch category. To test hypothesis 3, the results of the question, "What do you see as the biggest challenge(s) to getting humans to Mars?" is examined. The survey allowed respondents to choose from technical challenges (human based and hardware based) as well as political challenges (funding and public support) or to write in their own challenge. The write-in answers were put into one of these two categories when possible, or omitted if they did not fit either category.[7] Technical responses were coded as 1 and political responses were coded 0.

III. Results

Perhaps somewhat surprisingly, the data does not support hypothesis 1. As shown in Table 1, respondents from countries with no space program are seen to be most optimistic about sending humans to Mars by 2033. Moreover, despite the small sample sizes, the differences between the

[4] While respondents came from 30 different countries, the low overall number of respondents prevents a country by country analysis.
[5] While the Space Shuttle program ended in 2011, the United States still retails the technological capabilities of sending man into space. The economic and political reasons for not engaging in human spaceflight does not change the technical ability and thus may have unique effects on inspiration.
[6] There are many other ways to create groups with this data. For example, many countries have astronauts that are not able to launch cargo. They team with other nations to send their astronauts to space. It is unclear if changing the latter two groups: "launch capability" and "no launch capability", to "has astronauts using the launch capabilities of a partner nation" and "has no astronauts", would yield different results.
[7] Only three responses were omitted.

most developed space programs (human launch capability) and the other two categories are statistically significant.[8]

Table 1: Average level of belief in ability to send humans to Mars by 2033 by launch capability

	Mean	**Std. Dev.**	**N**
No Launch Capability	0.857	0.363	14
Cargo Launch Capability	0.804	0.401	51
Human Launch Capability	0.564	0.502	39

There are many factors that could contribute to why people from nations with more capability in space are less likely to feel people are ready to go to Mars. Prior failures and an understanding of the technological challenges that exist in such a complex endeavor could feed this pessimism. Moreover, this effect could be due to failures and setbacks these nations have endured.

In order to examine hypothesis 2, the initial categories of space programs have been further subdivided as seen in Table 2. Here we consider some of the factors that are happening among the countries within the groups. For example, China and Russia are more similar to each other than they are to the United States in regards to political will and current technological advances. China is currently pushing the frontier in space as they have made a lot of recent investment and technological progress, putting momentum on their side. Russia, meanwhile, can still send manned missions and has been for decades, always stepping forward, albeit slowly at times, but rarely taking a step back technologically. The United States, on the other hand, has seen a loss in momentum and setbacks including currently being unable to launch government funded manned spacecraft, but private companies through government funded initiates are seeking to fill this gap.

In order to examine the impact of setbacks and failure on inspiration, the respondents from the United States can be compared to respondents from Russia and China. As seen in table 2, the average difference between the respondents is 0.21,[9] or that respondents from the United States are 21 percent less likely to believe that we will have the ability to send humans to Mars by 2033.

[8] A P-value test was used to compare each of the groups. No significance was found between views of people from countries with cargo and no launch capability (as is also evidenced by the similar means). The differences between human launch capability and the other two groups is significant: p=0.0136 for cargo launch and p=0.0511 for no launch capabilities. While the 0.0511 is not quite significant at the standard .05 level this is likely due only to the small sample size.

[9] Due to the small sample size, this is not a statistically significant difference.

Table 2 also shows that respondents from countries with an unmanned launch capability, that are not part of the European Space Agency (ESA) are the most optimistic, followed by people from countries without any national space launch capability. This suggests that people from less developed space nations are more likely to believe that sending humans to Mars is feasible in the near term. This is a very peculiar finding that questions the idea that technological progress is a driver of space inspiration.

Table 2: Average level of belief in ability to send humans to Mars by 2033 by country groupings

	Mean	**Std. Dev.**	**N**
United States	0.543	0.505	35
Russia/China	0.75	0.5	4
European Space Alliance	0.733	0.450	30
Other countries with cargo launch capability	0.904762	0.301	21
Countries with no launch capability	0.857	0.363	14

To further unpack this story of technology and inspiration, respondents were asked what they saw as the challenges to getting humans to Mars. Here, in regards to hypothesis 3, a different narrative comes to light. Respondents from the United States are more likely to see challenges as political: related to public support and funding, rather than technical. Conversely, respondents from Russia/China see the challenges as technical. Within countries with cargo launching capabilities, respondents from ESA countries are slightly more likely to see challenges as technical as compared to respondents from other countries with cargo capacity seeing the challenge as almost equally technical and political. Interestingly, respondents from countries with no launch capabilities are also more likely to see the challenge as political.[10] Therefore, hypothesis 3 is only minimally supported.

[10] Due to the small sample sizes, most of the differences are not statistically significant.

Table 3: Barriers for Ability to Send Humans to Mars (Technical vs Political)

	Technical	Political	Mean	Std. Dev.	N
United States	14	21	0.4	0.497	35
Russia/China	3	1	0.75	0.5	4
European Space Alliance	16	12	0.571	0.504	28
Other countries with cargo capability	10	11	0.476	0.512	21
Countries with no launch capability	5	11	0.333	.498	15

Despite the low sample size, an attempt was made to examine the probit regression of a model that attempts to predict a respondent's belief in ability to send humans to Mars by 2033. This is done while controlling for characteristics that could inhibit or inspire such a belief, including: the capability of their nation's space program, the type of challenge they see, and nation-based controls for the United States and ESA member countries. No variables were found to be statistically significant at the $p<.05$ level.

IV. Discussion & Future Research

This study set out to answer an important question, "Does having a national space program provide a measurable inspirational effect?" However, the results are murky at best. It does not appear that having a space program alone is directly correlated with inspiration as measured here – belief in mankind's ability to reach Mars by 2033. What this study did do is open the door to the discussion of space as a possible inspirational force and in doing so yielding some interesting findings.

The results show that there are some interesting relationships between what is happening within a country in regard to space exploration and the belief of that country's citizens that sending humans to Mars is a feasible task. This suggests that a nation's space program can indeed inspire people to dream about the possibilities that space exploration has in store for the future under the right conditions. Or to put it more simply, that successful space exploration does indeed inspire. However, it is not as simple as one might at first think, as progress itself does not appear to be the driver of inspiration. There are a lot of nuances in regards to the data and the methods used here. It should be kept in mind that the goal of this study has been to start the discussion into these ideas, not to be a definitive answer.

From the analysis, we do not see clear support that a highly capable space program is the key to higher levels of inspiration. However, there is evidence to support the idea that more technology leads to more inspiration. But, there appears to be a threshold. The United States is the only country to have stepped back in space capability (while it allows the private sector to build up capability) and perhaps these perceived setbacks have had a shocking effect on inspiration. Once the United States has finished building its commercial crew capability, this study should be conducted again to see determine if there is any change.

In the meantime, what we see here in regard to setbacks and their impact on inspiration is perhaps as good a reason as any to increase international cooperation to help avoid the appearance of ever having to again take a step backwards in relation to space exploration. Cooperative international efforts have led to humans living in the most inhospitable places on Earth, such as the Antarctic, so perhaps similar efforts will help humans reach Mars.

This article is but a starting point, especially in terms of methodology. The small sample and metric used here to measure the inspirational ability of a space program is far from ideal. The sample is limited to only about 100 space-interested young people (under 35 years of age). A larger sample size is desired in order to get more concrete results and in order to use more advanced statistical analysis. It would be useful to examine similar data on the general public as opposed to space interested young people to see if the views are similar. However, the general public's answers may be too sporadic as people who do not care about space or ignore it are also unlikely to be inspired by it. More importantly, space interested people may not even be the same across the globe. Perhaps those who identify as space interested from countries without space programs are extreme optimists. These same people may have been inspired by global space success as a whole rather than their individual national programs; while someone from the United States could not be subject to such a confounding effect. More nuanced questions and multivariate analysis are required to get at this piece of the puzzle.

In putting this article together, we considered other ways to measure inspiration, but were at a loss on how to do so in a better way than we did here. While other models of study could and should be considered, they come with their own limitations. One such example would be comparing feelings towards Mars within the United States pre-and post the shuttle grounding to better test the theory of scientific setback. It would also be interesting to bring in questions related to the successful landing on Mars of the Curiosity rover in 2012 and the incremental successes of the private companies competing to provide launch services for NASA through the Commercial Crew program. However, this research design presents an inherent problem, the inability to control for a number of potentially confounding factors given the scarcity of broad based public opinion polling on Mars, or space issues in general for that matter. Additionally, questions about Curiosity or private space successes may act as a priming agent, which may bias results.

One way that we do see as potentially valuable would be to look at the relationship between space success and educational achievements. Considering the political discourse around the inspirational value of space and the ties to STEM (science, technology, engineering and math) education efforts, another way to explore this relationship may be to examine if successful space missions are related to student pursuit of such fields. There would be many complications of such a study, including dealing with external factors that may also be related to why students choose to pick STEM fields, but given the outcome of the 2009 Nature survey mentioned earlier, such a connection is clearly worthy of study.

Often, inspiration is studied from the point of view of a religion scholar or philosopher, so we challenge others in these fields, or other fields, to continue this line of research into the inspirational value of space. However, we hope that future studies continue our attempt to put a metric on inspirational value that can be compared across people or society in order for future research to be able to make comparisons and help with our understanding of the relationship of space exploration and inspiration in meaningful and measurable ways.

Regardless, there is little quantitative research in this area to use as a guide. This article presents an initial step toward this understanding. We see this as a benchmark, a starting point, for the discussion between technological progress, political will and capability to send humans to space. We hope others will follow in our footsteps to better understand the inspiration value of space or even the sociological effects of space exploration more broadly. There are many unanswered questions that have been brought up here and can serve as a starting point for more in depth research. For example, does a national space program only inspire people within that country? Do space programs only inspire other space related endeavors, such as science fiction and studying science, or can the inspirational value of space be traced to other behaviors?

References

Bainbridge, William Sims. (1983). The Spaceflight / Revolution. Robert E. Krieger Publishing, Malabar, FL.

Collins, Eileen & Nick Lampson. (2013). "Beyond the Politics: Space Exploration Is Imperative to Innovation and Inspiration" *Huffington Post*. June 13. Retrieved from: http://www.huffingtonpost.com/eileen-m-collins/space-exploration_b_3436866.html.

Frutkin, Arnold W. (1965). International Cooperation in Space. Prentice Hall Inc., Englewood Cliffs, NJ.

Incerti, Manuela, Fabrizio Bonoli & Vito F. Polcaro. (2011). "Transient Astronomical Events as Inspiration Sources of Medieval and Renaissance Art." In Enrico Maria Corsini, Ed. The Inspiration of Astronomical Phenomena VI. Astronomical Society of the Pacific Conference Series, Vol 441: 139-150.

Kridge, John. (2009). "NASA's International Relations in Space, An Historical Overview." In Steven J. Dick, ed. NASA's First 50 Years: Historical Perspectives. U.S. Government Printing Office. 109-149.

Launius, Roger D. (2003). "Public opinion polls and perceptions of US human spaceflight." *Space Policy* 19 (3): 163-175.

Logsdon, John M. (2009). "Fifty Years of Human Spaceflight, Why is There Still a Controversy?" In Steven J. Dick, ed. NASA's First 50 Years: Historical Perspectives. U.S. Government Printing Office. 275-285.

McCurdy, Howard E. (1997). Space and the American Imagination. Smithsonian Institute, Washington, DC.

Michaud, Michael A. G. (1986). Reaching for the High Frontier: The American Pro-Space Movement, 1972-84. (Praeger Publishers, New York, NY).

Miller, Jon D. (1987). “The Challenger accident and public opinion: Attitudes towards the space programme in the USA.” *Space Policy* 3(2): 122-140.

Molaro, Paolo & Pierluigi Selvelli. (2011). “A Telescope Inventor’s Spyglass Possibly Reproduce in a Brueghel’s Painting.” In Enrico Maria Corsini, Ed. The Inspiration of Astronomical Phenomena VI. Astronomical Society of the Pacific Conference Series, Vol 441: 13-21.

Monastersky, Richard. (2009). “Shooting for the Moon.” *Nature*. July 15. Retrieved from: http://www.nature.com/news/2009/090715/full/460314a.html.

Moore, Chadwich A., Angela M. Richman & Van D. Chamberlain. (2011). “Finding Inspiration in the Face of Endangered Starry Skies.” In Enrico Maria Corsini, Ed. The Inspiration of Astronomical Phenomena VI. Astronomical Society of the Pacific Conference Series, Vol 441: 451-460.

Price, Hoppy, Baker, John, Naderi, Firouz. (2015). “A Minimal Architecture for Human Journeys to Mars.” *New Space* 3(2).

Van Allen, James A. (2004). "Is Human Spaceflight Obsolete?" *Issues in Science and Technology* 20, no. 4.

Criteria for Sustainability in the Orbital Environment

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ABSTRACT - Space debris continues to be a growing problem that affects a wide variety of stakeholders in the space environment. For example, the cupola on the International Space Station recently suffered damage after being hit by a small piece of debris smaller than a millimeter (Griggs, 2016). Although several solutions have been proposed, progress on the policy front remains slow. Understanding the interests of the myriad stakeholders affected by the problem and developing criteria to evaluate workability are crucial first steps that need to be taken before any proposed solution can be implemented. The debris issue has been characterized as a "tragedy of the commons," a concept first popularized by ecologist Garrett Hardin (1968) to describe common-pool resource (CPR) problems. These are problems in which multiple stakeholders rely on a resource, but none own it or are in charge of maintaining it for future use, leading to ruin for all. Later work by Elinor Ostrom (1990) critiqued Hardin's theory that privatization or government takeover were the only possible solutions to CPR problems, finding numerous real-world examples of resource appropriators, local officials, and other stakeholders successfully working together to manage CPRs. However, more recent scholarship has argued that Ostrom's framework may not translate directly to every CPR management issue, particularly when looking at global commons such as the oceans, the atmosphere, and outer space, due to issues of size and scale. Still, as the Secure World Foundation's Brian Weeden and Tiffany Chow (2012), and the Naval War College's Joan Johnson-Freese (2012) have noted, Ostrom's framework seems to provide a solid foundation for addressing orbital debris and wider questions of space governance, although it is in need of modification. Likewise, work by Paul Stern of the National Research Council concludes that Ostrom's framework can be useful for governing both the global commons and the risks of emerging technologies with the addition of further principles. Building on the aforementioned research, this article expands on the efforts to adapt Ostrom's framework and principles to the issues of space debris and space governance. It surveys the approaches used in the management of comparable global commons—including the atmosphere, the Antarctic, the oceans, the emerging commons of the Internet, and existing efforts regarding the orbital environment—and summarizes the lessons they can provide for the debris issue. It also seeks to fully elucidate the interests of each stakeholder group, from established space powers to developing countries, businesses, and the global public in order to develop a set of evaluative criteria that any solution must

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meet in order to have a chance at both policy effectiveness and political adoption. Finally, this article applies these criteria to a sample set of proposed solutions to the orbital debris problem in order to illustrate their practical utility.

I. Introduction

Orbital debris is a problem as old as human spaceflight. Beginning with the Soviet Union's launch of Sputnik in 1957, each object launched into space has left its mark on the orbital environment in the form of debris. Ranging in size from chips of paint, and loose nuts and bolts, to spent rocket boosters and full-sized but no longer functioning satellites, these pieces of debris can remain in orbit for years or even decades depending on their altitude, speed, and other factors (Moltz, 2014). Due to the physics of spaceflight, every single piece of debris represents a threat to operational spacecraft, their crews, and the users and operators on the ground who benefit from the use of space. With an increasing number of nations, corporations, nongovernmental organizations (NGOs), and everyday citizens pursuing space access and becoming dependent on space-based technologies each year, dealing with the orbital debris issue is an increasingly prominent topic in policy circles.

Scientists and policymakers first took note of the orbital debris issue in the late 1970s. By this point in time, humans had been launching spacecraft into Earth orbit for some twenty years and scientists were interested in gaining a better understanding of what kinds of long term threats spacecraft faced in their environment. The prevailing assumption was that natural micrometeoroids were the major threat about which spacecraft operators and scientists needed to worry. However, a NASA study by Donald Kessler and Burton Cour-Palais (1978) determined that this was incorrect and that collisions with other satellites, including discarded rocket motors and other fragments of man-made material, were a greater concern. The model developed by Kessler & Cour-Palais (1978) produced the following four specific conclusions:

1. The collisional breakup of satellites would become a source of new debris in the near future, possibly before the year 2000.
2. Once the process of breakup from satellite-to-satellite collisions began, the amount of debris in certain orbital regions could quickly surpass the amount of natural meteoroid debris and present a greater threat to spacecraft.
3. Over a longer time period, the size of the debris population and its rate of growth would increase exponentially through debris-debris collisions, even if net input of new debris from launches was reduced to zero.
4. The processes that produced debris fragments would be analogous to those scientists believe created the asteroid belt between Mars and Jupiter during the formation of the solar system.

In essence, the study found that collisions between man-made satellites in Earth orbit would create many smaller pieces of debris that could each cause new collisions. As the debris population grew over time in this fashion, the chances of the debris creation process becoming self-sustaining would increase. The worst-case scenario became known as the Kessler Syndrome. In a Kessler scenario, the orbital debris population reaches a tipping point at which a single collision sets off a chain reaction of new debris creation and new collisions. Such a series of events could render parts of the orbital environment unusable within a matter of hours depending on the exact conditions at the time of the incident. The affected portions of the orbital environment could remain unusable for several years or decades afterward (Kessler & Cour-Palais, 1978).

Although the most extreme interpretations of the Kessler Syndrome have achieved somewhat of a cult status in the media over the years (see the recent film *Gravity*, for example), more recent studies point out that the buildup of debris and subsequent degradation of the orbital environment is likely to take place more slowly, possibly over the course of a few decades (Kessler et al., 2010). Still, a sudden event such as the use of a weapon in orbit as demonstrated by the Chinese in 2007, and the US and Russia on other occasions (Moltz, 2014), or a major accidental collision could accelerate the process significantly. Kessler himself recently pointed out that we are already several years into this slow process of degradation and that the world must act today to prevent the entry of new debris into the orbital environment and begin physically removing large pieces already in orbit to slow or reverse the Kessler process (Burns, 2013).

After Kessler's initial study, spacecraft operators from national governments and the private sector continued to study the orbital debris problem and attempted to monitor and mitigate it to the extent possible. Current estimates from the United States, which has the most effective tracking system available, estimate that there are roughly 21,000-23,000 objects in Earth orbit that are 10 centimeters in diameter or larger (Loomis, 2015; Anzaldua & Dunlop, 2014). These estimates include about 1,000-1,100 active satellites and the International Space Station (ISS). Everything else being tracked is debris. However, objects as small as 1 cm in diameter are considered a threat to orbiting spacecraft like communications satellites and the ISS, and unfortunately these cannot all be tracked with current technologies. Experts put the total population of space debris including undetectable objects at anywhere from 500,000 on the low end to hundreds of millions on the high end (Loomis, 2015; Anzaldua & Dunlop, 2014). These numbers give a sense of the scale of the problem that spacecraft operators face.

In addition to the size and number of debris objects, their specific location in orbit is important. Earth orbit is primarily divided into three regions: Low Earth Orbit (LEO), extending to an altitude of 2,000 km; Geosynchronous or Geostationary Orbit (GEO), which exists as a narrow band at about 35,786 km; and Medium Earth Orbit (MEO) covering altitudes between LEO and GEO. There is an additional orbital classification known as Highly Eccentric/Elliptical Orbit (HEEO), though it is rarely used by spacecraft operators. Unsurprisingly, the highest concentrations of debris are found within LEO, which is the most heavily used region in the orbital environment (McCormick, 2013).

LEO is home to the International Space Station and several hundred satellites used by both national governments and private companies for telecommunications, intelligence gathering, weather monitoring and forecasting, and other purposes. Some examples of at-risk satellites in LEO are the Iridium constellation of 66 satellites owned by Motorola at 781 km, and the 52 Globalstar satellites orbiting at 1440 km that provide satellite phone service (Anzaldua & Dunlop, 2014). Debris also exists at MEO and GEO, but those regions are less crowded and their satellite populations are considered less threatened than the population in LEO (McCormick, 2013).

II. Framing Space as a Tragedy of the Commons, CPR, and the Issue of Emerging Technology

Once the reality of the debris threat was realized, policymakers slowly took steps to address the problem. However, like many other environmental problems, orbital debris is a complex issue that does not lend itself to easy, one-size-fits-all solutions. While a variety of solutions have been proposed, global agreement on policies to implement them remains elusive. In light of this, some have described the orbital debris problem as an example of a "tragedy of the commons," which was first described in ecologist Garrett Hardin's famous essay of the same name (Hardin, 1968). In Hardin's original scenario, groups of resource appropriators all depended on the same common-pool resource (CPR) for their livelihood. Typical examples here are grazing fields for cattle, fishing grounds, forests, and other natural resources. Since resources like these are open to all and no one person or group is charged with their care, each appropriator enters into a zero-sum competition with the others to maximize their gain from the CPR before it is used up. This is a classic example of a prisoners' dilemma, which implies that two or more rational actors competing over the same thing will always seek maximum personal benefit and forego cooperation. In CPR scenarios, this dilemma ultimately leads to degradation of the resource and losses for all appropriators who depend on it. Hardin surmised that there were only two possible solutions: privatization of the CPR that incentivizes appropriators to maintain it for their continued use, or takeover of the CPR by a powerful government entity capable of maintaining the resource for all and regulating its use.

However, later work by Elinor Ostrom found that Hardin's conclusion was not supported by empirical evidence. In her seminal 1990 book, *Governing the Commons*, Ostrom found that there were many real-world examples of resource appropriators, local communities, government officials, and others working together to effectively manage CPRs without turning to complete privatization or government takeover as Hardin theorized. Ostrom's study looked at rural forests and meadows in Switzerland and Japan, local irrigation systems in Spain and the Philippines, Turkish fisheries, and groundwater supply systems in California. From these case studies, she created a framework of eight broadly defined principles that she found in successful CPR management systems. While her principles are not guarantees of success in managing CPRs, they do provide an excellent framework for analysis. Ostrom's principles are presented in Table 1 below (Ostrom, 1990).

Table 1: Principles of Successful CPR Management Systems (Ostrom, 1990, p. 90)

1. Clearly defined boundaries
   Individuals or households who have rights to withdraw resource units from the CPR must be clearly defined, as must the boundaries of the CPR itself.
2. Congruence between appropriation and provision rules and local conditions
   Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money.

3. Collective-choice arrangements
   Most individuals affected by the operational rules can participate in modifying the operational rules.
4. Monitoring
   Monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.
5. Graduated sanctions
   Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.
6. Conflict-resolution mechanisms
   Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
7. Minimal recognition of rights to organize
   The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

For CPRs that are parts of larger systems:

8. Nested enterprises
   Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities, are organized in multiple layers of nested enterprises

Ostrom's work revolutionized the way scholars approached the study of CPR problems and the design of systems to address them. However, the cases she studied were all at the local or regional level and thus it became clear that there were problems with transferring them to larger, global-scale CPR issues. One of the primary challenges presented by global commons as opposed to local or regional ones is their complexity. In fact, they often overlap with each other and with other smaller-scale commons to produce conflicting social interpretations of the problem for different cultures and stakeholder groups (Ostrom et al., 1999; Vogler, 2012). An example of CPR overlap at the global level is the complex relationship between preserving biodiversity and addressing climate change. Similarly, the more complex interactions among collective actors like nations or multinational companies present challenges not found in more personalized, face-to-face interactions at the local level. Later in this article, Ostrom's framework is applied to the orbital environment and her principles are used as the basis for developing a set of criteria for evaluating proposals to address orbital debris and promote space sustainability.

Emerging technologies can also be included here since they often share many of the same societal benefits and risks as natural CPRs do. For example, the Internet provides valuable communications and commercial services to billions worldwide, but it also represents a concern for governments and the public in terms of national security and certain types of crime. Space fits into both categories well. The orbital environment is the largest commons in existence and many of the technologies involved in its use are relatively new or still in development. The US military and others are now heavily dependent on space capabilities for their operations. Additionally, companies and the public increasingly rely on satellites for commercial services and other needs, and scientists depend on space to carry out a variety of research related to Earth science, astronomy, and other disciplines. For these reasons, scholars have begun to identify the Internet and space as pressing areas in global commons governance along with the atmosphere, the ocean floor, and the Antarctic (Vogler, 2012; Stern, 2011).

Paul Stern (2011) of the National Research Council explored how to adapt Ostrom's principles to emerging technologies and global commons. Stern found that they were plagued by similar problems such as scientific uncertainty regarding the degradation of the commons or impacts of the technology, complexity of governance choices, multidimensionality of risks, value conflicts and uncertainties, potential for mistrust, and varying time horizons and pressures. He developed a set of additional principles to address these scaling issues, which are useful for adding depth to the current analytical framework. Stern's additional principles for governing emerging technologies and global CPRs are presented in the table below, along with their challenges in implementation in the right-hand column (Stern, 2011). Later, Stern's principles will also be applied to the orbital environment to help develop this author's proposed criteria for sustainability.

Table 2: Additional Principles for Management of Emerging Technologies (Stern, 2011, p. 220)

Additional principles		
Invest in science	Yes	• Scientific results are uncertain • Incentives for interpreting uncertainty to favor one's interests • Science may not be credible to users
Integrate scientific analysis with broadly based deliberation	Yes	• Determining when and how best to engage the scientists with the interested and affected parties
Plan for institutional adaptation and change (iterative risk management)	Yes	• Designing learning institutions • Incorporating science into an updating process
Engage a variety of institutional types	Yes	• Designing effective combinations of institutional types

III. Identifying Stakeholders in the Orbital Environment

Each group of stakeholders in the orbital environment and their interests will be examined before exploring the history of space governance and attempts at addressing the orbital debris issue. Doing so will help to understand the evolution of the current space governance system and analyze ways in which it might be improved. Further, it will allow for an analysis and critique of attempts to apply Ostrom's principles to the orbital debris problem. The groups examined consist of national governments, the private sector, and global civil society.

a. National Governments

The most powerful and experienced group of stakeholders in the orbital environment is national governments. After all, it was the former Soviet Union that launched humankind's first artificial satellite into orbit, kicking off the 20th century space race that culminated with a prestige victory for the United States when the *Apollo 11* mission landed on the Moon in 1969. From its beginnings as a new avenue for nationalistic competition between the superpowers during the Cold War, space activities worldwide have evolved into much more. Space is now used by a variety of governments for official communications, weather forecasting, development and urban planning, and scientific research and disaster relief (UN, 2006). However, for established space powers like the United States, space remains an important component of military operations and international relations.

Military concerns have become even more prominent for nations like the United States due to the rapid growth in the number of space actors in recent decades. Since 1990, the number of launching states and satellite operators has increased by roughly 50% from what it was during the Cold War, and it could potentially double by 2030 (Burzykowska, 2009). This has led many within the US defense community and related policy circles to describe space in the 21st century as a "contested commons" (Flournoy & Brimley, 2009; Moltz, 2014). In fact, a recent unclassified summary of the US National Security Space Policy described space as "a domain that is becoming increasingly congested, contested and competitive" (National Security Space Strategy, 2011). The report cited recent accidental collisions as evidence of congestion in important orbital slots, and also mentioned increasing use of the radio frequency spectrum used by orbiting satellites, which could lead to accidental interference. It also noted advances in the capabilities of more states and non-state actors to threaten space assets, either with physical force or electronic interference as evidence of space becoming increasingly contested. Finally, it noted that while the US still enjoyed an overall edge in space-related capabilities, technical progress worldwide was beginning to close the gap, leading to an increased reliance in the US space industry on foreign components—a potential source of weakness as far as security and foreign policy are concerned. In light of all these developments, US defense officials have made maintaining US freedom of action and dominance in the space domain a top priority going forward into the 21st century (Moltz, 2014; Martin, 2015).

Obviously, the US is not the only nation that views space as an essential component of its defense and national security strategy. In fact, for some the United States' dominant position in space is a primary concern. Nations like China are developing asymmetric capabilities like anti-satellite (ASAT) weapons and jamming technologies designed to at least temporarily disable or impede space capabilities that the US would rely on in any potential conflict (Moltz, 2014; Martin, 2015). This is a classic example of the sort of mutual suspicion that can lead to an arms race, which experts like Moltz (2014), David DeFrieze (2014), and Scott Shackelford (2014) agree would be very dangerous for the future of the space environment given its already degraded state. Despite the broad realization of the mutual risks involved, the nature of the international system and state sovereignty make it unlikely that the US, China, or any other nation will fully turn away from developing military space capabilities and methods to counter them in the near term.

In addition to defense and military concerns, space also holds great importance to an increasing number of national governments for scientific, economic, and domestic political reasons. Nations increasingly rely on space for telecommunications, weather, climate, and geographic data used to support a wide variety of public services, technology and industrial development, and scientific research. A 2009 study of six major space agencies from around the world showed that expenditures for each were steadily on the rise and that their strategic orientations reflected an interest in each of the aforementioned areas, as well as an interest in boosting national pride and international prestige through the development of space capabilities (Petroni et al., 2009).

In the US, the National Aeronautics and Space Administration (NASA) and other agencies like the National Oceanic and Atmospheric Administration (NOAA) are equally reliant on space for civil and scientific uses. They are increasingly interested in international collaboration on scientific missions as well to spread costs, build relations, and increase the capabilities of missions and programs focused on Earth sciences as well as deep space exploration (NASA Authorization Act of 2010; ISECG, 2007). However, whether intended for Earth orbit or deep space destinations like Mars or the outer planets, any government sponsored scientific mission will be vulnerable to space debris, at least in its early stages during and shortly after launch. NASA and its International Space Station partners are well aware of this fact, given the multiple collision warnings they receive per month, some of which require moving the ISS into a safer orbit and burning valuable fuel in the process (House, 2009).

Debris also presents a threat to the global economy. Estimates say the space economy produces some $320 billion in annual value for the modern world, with room to grow significantly in the near future (Anzaldua & Dunlop, 2014). This economy could be destroyed by a sudden escalating incident or a long-term failure to address the debris issue, resulting in losses that could reach into the trillions of dollars depending on the length of the interruption to services that rely on space technologies (Moltz, 2014). Given the fragile state of many economies in the wake of the 2008 Global Financial Crisis, it is easy to conclude that space agencies and their parent governments would do well to avoid such a future shock.

As one might suspect, the views of national governments on space governance and the space debris issue are not uniform. In fact, these issues tend to split national governments along the lines of the "North-South divide," much like discussions about global environmental governance or development policy often do. Developing countries and newer space powers tend to view space as a domain that should be preserved for the benefit of all nations. In their minds, established spacefaring countries have reaped most of the benefits of space so far, and also share the bulk of the responsibility for creating the orbital debris issue through their activities. An example of this viewpoint can be seen in India's stance at the United Nations. India is both a developing nation and a rising space power. A summary of their position raises the following points: (1) the present debris population has been contributed to by various nations proportional to their level of activity; (2) keeping the space environment clean should be a top priority so future entrants to the arena will be able to utilize it without constraints; (3) debris information should be available in databases accessible to all member states of the UN Committee on the Peaceful Uses of Outer Space; (4) debris mitigation guidelines should be voluntary and enacted through national mechanisms; and (5) preserving the space environment should be a "common, but differentiated responsibility," meaning those nations largely responsible for the present debris situation and with the greatest ability to address it should take lead roles (Prasad, 2005). This viewpoint brings an element of social justice and equity to space debris mitigation and space governance debates.

The point about debris mitigation guidelines being voluntary and new entrants being able to operate in space without constraints also relates to the national security interests of India and other developing countries. These nations are worried that a treaty on space debris would share similarities with the 1970 Treaty on the Non-Proliferation of Nuclear Weapons (Moltz, 2014). This treaty awarded special rights to countries that had already tested nuclear weapons before it was signed, while imposing restrictions on nations that had yet to develop nuclear weapons. India and other space powers are worried that a treaty banning the development of anti-satellite (ASAT) weapons in order to prevent an arms race and preserve the space environment would create a "second class" of nations who would be vulnerable in comparison to nations like Russia, China, and the US that possess and continue to develop such weapons (Moltz, 2014). This is a dilemma that diplomats and policymakers must address as more nations enter the space domain and become more vocal about their interests there.

A final note should be made here regarding least-developed countries and developing countries with limited or no space capabilities. For example, many African nations are among those that could stand to benefit the most from the adoption of space technologies, and do to the extent that they possess the ability to use them for development, agriculture, disaster relief, and other purposes. However, few of them possess the institutional stability and industrial base necessary to pursue space access and utilization independently. Thus, few of them take an active interest in space governance or participate in the debate on how to address orbital debris (van Wyk, 2008). Yet, their interests are at stake, both today and in the future. For now, larger developing countries like India seem to share enough of the same concerns that they can represent least-developed and non-spacefaring countries by default to some degree, but that could change as India and others become more established in the space arena. The few emerging space powers that do exist in regions like Africa – Egypt, South Africa, Nigeria, and Algeria – will have to play a stronger role in shaping space governance toward their interests, and in establishing norms of behavior for their neighbors in the region (van Wyk, 2008).

b. <u>The Private Sector</u>

The next major group of actors in the space environment are private sector companies that operate satellite networks, provide launch services, and offer other goods and services that depend on space technologies. Many actors in this group have decades of experience in spaceflight and are capable of conducting operations on their own without the support of national space agencies, though governments are often among their biggest customers and may have been the primary source of initial funding in the case of newer companies. While spacefaring governments often rank national security as their primary concern in the space domain, the space industry's primary concerns are financial and economic. As mentioned previously, the global space economy is said to be worth some $320 billion annually (Anzaldua & Dunlop, 2014). Within that figure, the satellite industry alone is estimated to produce close to $200 billion in annual revenues when counting launch services, manufacturing, and ground-based applications. This market and related industries are growing as well, with the Satellite Industry Association (SIA) finding that global revenue from satellite based services (e.g., television) increased five percent to $118.6 billion from 2012 to 2013 (SIA, 2014). Orbital debris is a threat to the profitability of every firm in this market, so finding a solution to the issue is imperative from their perspective.

The threat presented by orbital debris is more troubling for companies from the so-called "NewSpace" industry. These are companies such as Virgin Galactic and Bigelow Aerospace in the United States that hope to carry paying tourists into space, eventually paving the way for cheaper, more frequent commercial flights, and possibly the development of privately owned space stations in orbit. Also included in this group are companies like SpaceX, Orbital Sciences, and Sierra Nevada that are taking over the role of providing access to low Earth orbit (LEO) from national space agencies like NASA and plan to offer their services commercially in the near future. The risk orbital debris poses to companies like these is more worrisome because of the potential for loss of human life during any accident involving a crewed vehicle. For NewSpace and well-established companies such as Boeing and Lockheed Martin, space debris is another policy issue that needs to be addressed for their business plans to move forward in an environment with minimal risk and uncertainty. For example, an issue they must address is insurance coverage in case of an accident. A study estimated that given the dangerous nature and somewhat spotty safety record of crewed spaceflight to date, commercial spacecraft will have to demonstrate between five and fifteen full test flights without incident before any insurance company would be willing to underwrite operational flights (Bensoussan, 2010). The current state of the debris situation adds another layer of risk on top of an already difficult and potentially deadly task for those seeking to build a commercial spaceflight industry.

Unfortunately for both established space firms and NewSpace upstarts, the rest of the global space governance system leaves much to be desired. Outside the US, UK, and a few other nations, governments have yet to lay out much of a regulatory framework that defines rules and guidelines for commercial spaceflight operators. Further, there are discrepancies and ambiguities between space law and aviation law, which is often used as a basis and de facto regulatory home for space operations despite major technical differences between the two fields. For example, in the US, commercial space launches are regulated by the Federal Aviation Administration (Mineiro & Michael, 2008; Crowther, 2011). At the international level, states are held responsible for all space activities launched from within their borders, meaning that under the current regime, companies planning to offer space tourism services are stepping into the realm of foreign policy, where private companies often are not given the same recognition as states and where states may be unwittingly taking on liabilities that do not serve their interests. Until uncertainties and shortcomings in global space governance – including debris mitigation – are addressed, the commercial spaceflight industry's progress toward maturity will face additional roadblocks (Mineiro & Michael, 2008; Masson-Zwaan & Freeland, 2009; Moltz, 2014).

c. <u>Global Civil Society</u>

The final group of stakeholders in the space environment is by far the largest and most diverse; namely, global civil society. This includes NGOs; universities and other educational institutions; local, regional, and international governmental institutions; citizen scientists; and every individual end-user of space-based technologies and services. The last group currently numbers in the billions. If we assume continued expansion in the use of space technologies in the near future, then we must ultimately include every living person on the Earth. Given the sheer size of this stakeholder group, their concerns and interests are difficult to fully map and may, in fact, overlap or conflict with the interests of the private sector and national governments detailed in the previous sections. As Stern (2011) noted in his attempt to apply Ostrom's principles to global commons and emerging technologies, this mixture of individuals and organizations makes for an incredibly complex set of interactions and motivations in space governance.

Nevertheless, some claims are possible about the general interests of global civil society when it comes to the space environment. For example, citizens in established space powers and developed nations benefit from a variety of services and public goods provided by satellites and space technologies. Examples here include national defense, communications and entertainment, electronic banking, GPS navigation, and weather forecasting. Essentially, anyone with a cell phone can be described as a beneficiary of space technology in today's world. In emerging space powers and developing countries, citizens benefit from agricultural planning, development services, the coordination of disaster relief and management, conflict and human rights monitoring, as well as some of the same services citizens in the developed world enjoy (UN, 2006). All of these services provided by space technologies address quality of life issues for citizens in both the developed and developing world. Orbital debris is a threat to their current quality of life and future improvements to it that may arise through developments in space technology.

Beyond individual citizens are the variety of civil society organizations that benefit from space technologies, including educational institutions, NGOs, local governments, and similar entities. Many of these organizations also play a major role in the provision of services listed in the previous paragraph either through the direct provision of satellite service or by pressuring national governments to use them (Chow & Weeden, 2013). The capabilities of these organizations to engage in space activities are advancing due to the expansion of CubeSat applications throughout the world.

CubeSats are small satellites usually no larger than a shoebox and weighing less than 15 kilograms that can launch into orbit as secondary payloads on rockets launching larger, more typical satellites. This secondary payload capability and their modular design make CubeSats incredibly cheap and easy to build for a variety of organizations. Their total costs are typically in the low millions of dollars, and may reach as low as six figures in the near future. Several universities and even some select high schools around the world have pursued CubeSat projects on their own. Private sector companies from Google to small startups have also taken an active interest in CubeSat applications, while some national governments unable to afford more traditional space programs have developed CubeSats as their first national spacecraft (Woellert et al., 2010).

CubeSats are democratizing space access like never before, which is largely a positive development. However, the huge number of new actors they may bring to the domain will need to be included in the future of space governance and debris mitigation. CubeSats themselves also represent an additional complication for debris mitigation efforts depending on where they are deployed and how long they stay in orbit (Moltz, 2014). Balancing the benefits, they could potentially provide to millions of people against future efforts to preserve the space environment is a critical issue for policymakers to address going forward.

It is also worth noting the different moral and ethical interpretations of space governance and the orbital debris issue that exist within global civil society. There are significant differences in how populations and institutions in developing countries view fairness in the distribution and development of space resources and technology. This echoes what is often seen in debates over other questions of global governance concerning the environment, development, and technology. For example, in the US and to some extent in Europe, views about technology development and resource distribution tend to be more laissez-faire and business oriented, while many in the developing world tend to take a more communal approach and favor policies that would see more equitable distributions of space resources and encourage technology transfers from the developed to the developing world (Rathman, 1999). These conflicts could become more prominent in the near future as the commercialization of space accelerates alongside the development of emerging space powers and the growth of civil society participation in space (Rathman, 1999).

Lastly, there are broad ethical and moral questions about preserving the heretofore pristine space environment for future generations as humanity begins to add Earth's orbital environment, the Moon, and eventually other parts of the solar system to its sphere of economic and cultural activity. Failure to address such questions early in the Industrial Revolution contributed to the rise of many of the environmental problems that exist on Earth today, and similarly, the lack of a strong moral and ethical code early in the Space Race contributed to the current problem with orbital debris (Williamson, 2003). Fair, open, and honest dialogue in attempts to reshape and reform space governance going forward will be critical to addressing these issues effectively.

IV. History and Current State of Space Governance and Debris Mitigation

Space governance was born shortly after spaceflight itself. During the Cold War, the two camps came together under the auspices of the United Nations to negotiate a framework for the conduct of operations in this new frontier of human activity. The result was the 1967 Outer Space Treaty (OST), which forms the basis of space governance today. The treaty contains the following major stipulations and restrictions: (1) required that exploration and use of outer space be carried out for the benefit of all humankind; (2) prohibited claims of national sovereignty over celestial bodies like the Moon; (3) forbade deploying nuclear weapons or weapons of mass destruction in outer space; (4) established national liability and responsibility for all space activities originating from within national borders; (5) limited the use of the Moon and other celestial bodies to peaceful purposes; and (6) stipulated that astronauts from all nations were the envoys of humankind and must be treated properly by all (Outer Space Treaty, 1967).

The 1979 Moon Agreement (or "treaty"), which went into force in 1984, established the "Common Heritage of Mankind" (CHM) principle for the space environment, a legal principle used in other fields of global governance that developed in the mid-twentieth century as the Space Race accelerated and concerns about environmental issues began to rise worldwide. This principle states that global commons are held by all humankind and not subject to appropriation by any single nation or private entity. The CHM principle has sparked disagreement about the distribution of resources, establishing property rights, and providing technical assistance to developing nations in subsequent negations over domains such as the ocean floor, and more recently, outer space.

Critics of CHM claim that it is ineffective at managing the global commons in the face of technological advances that open up previously inaccessible regions for use by human civilization. Further, they note that CHM runs contrary to the Westphalian concept of state sovereignty that has defined the international political system for several centuries, which helps fuel the divide mentioned earlier between developed and developing nations on global commons governance. However, they also note that privatization along the lines of traditional national property rights systems found in the West are ill-suited to preventing tragedy of the commons scenarios from developing because of differing cultural viewpoints regarding property rights at the global level. Instead, they argue for more multilateral approaches that allow for the inevitable economic exploitation brought about by technological advancement while also preserving the commons for future use (Shackelford, 2009). A revisit of the debate about CHM will occur later in this article.

Around the same time the OST was being negotiated and enacted, various nations proposed additional ideas. Some suggested the formation of a global space agency modeled on the International Atomic Energy Agency (IAEA) to monitor space activities and facilitate technology transfers to developing nations. The superpowers, busy with their Space Race, did not support this idea. As the race wore on and the Soviets and Americans began to land rovers and astronauts on the Moon, other countries, for example India, became concerned that the superpowers would attempt to stake territorial claims on the lunar surface, leaving the rest of the world out and potentially paving the way for armed conflict on the Moon and in orbit (Moltz, 2014). This concern led to the creation of the 1979 Moon Treaty at the UN, which called for an international organization that would manage and distribute all resources from future economic activities on the Moon and ensure an "equitable sharing" of benefits that accounted for the needs of developing countries. The established space powers ignored the Moon Treaty, and in the end, it was only adopted by a small number of non-spacefaring nations. It is widely regarded as a failed treaty (Moltz, 2014). The Moon Treaty's failure demonstrates the conflicting moral and ethical viewpoints in the developed and developing worlds when it comes to space governance, which were noted earlier.

While attempts at expanding space governance through formal treaties and international organizations fizzled out, there were successes in other areas. For example, after fatal accidents in both the Soviet and American space programs, the two sides signed the Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space (or "Rescue Agreement") in 1968. This agreement required that both sides assist and return each other's spacecraft and their crews if they ran into trouble or landed outside their home territory. In addition, after a spike in Cold War tensions in the late 1970s and 1980s led to tests of anti-satellite (ASAT) weapons by both sides, realization of the threat posed to all by the use of space weapons capable of destroying satellites and the massive amounts of debris they would create dawned on policymakers in both East and West. As a state of détente arose after this period of tension, an unspoken protocol took shape prohibiting the testing or use of ASAT weapons in order to protect space from the debris fields they would generate (Moltz, 2014).

Initial cooperation between the Soviets and Americans grew to include Japan and the European Space Agency, resulting in the formation of the Inter-Agency Space Debris Coordination Committee (IADC) in 1993 to coordinate debris mitigation activities between these countries' space agencies (Moltz, 2014). The IADC issued a set of voluntary debris mitigation guidelines that called on states to refrain from the creation of debris lasting longer than 25 years, and to deorbit satellites in LEO at the end of their service lives, or conversely to boost satellites in GEO to higher, super-GEO orbits to avoid collisions after they were decommissioned. Space agencies and many private sector actors began to voluntarily implement these guidelines in order to slow the creation of new debris. Some of the practices adopted included discontinuing the use of explosive bolts used in separating orbital stages and the "passivation" of boosters and upper stages of rockets by venting excess fuel to avoid the risk of future unplanned explosions.

As the Cold War ended and global activities in space increased heading into the twenty-first century, momentum built in the UN Office for Outer Space Affairs (UNOOSA) toward establishing the IADC guidelines as official guidelines of the UN. Negotiations picked up and the guidelines were formally adopted by the UN General Assembly in 2007, although compliance was still voluntary. (UN, 2007; Johnson, 2012). Despite their voluntary nature, the IADC/UN guidelines have had a major impact on reducing the rate at which new debris is placed into orbit. In addition, they have acted as a form of soft governance by establishing expected norms of behavior for space operations, allowing major government and private sector actors to set the tone for emerging space actors as they enter the field (Johnson, 2012). National governments in the US, Russia, Japan, China, and several European countries have also taken steps to codify the guidelines as mandatory law for space operations originating within their borders and tasked regulatory agencies like the Federal Aviation Administration (FAA) and Federal Communications Commission (FCC) with enforcing them (Johnson, 2012). These guidelines and the bottom-up, voluntary nature in which they have been developed and implemented provide an illuminating example of progress in how to address the orbital debris issue going forward.

a. Recent Events and Current Issues

While the IADC/UN guidelines have been a major success at curbing the flow of new debris into Earth orbit, they do not address the considerable population of debris that already exists there. Existing debris is what currently poses the greatest threat to spacecraft in orbit and is already capable of becoming self-sustaining on its own through the realization of the Kessler Syndrome. To make matters worse, a few recent incidents have occurred that demonstrate the seriousness of the debris threat and how the risks of a single incident can dramatically accelerate the debris creation process.

The first incident that highlighted the potency of the orbital debris threat was a sudden, unexpected ASAT test carried out by China in 2007. During the test, the Chinese targeted one of their own defunct satellites in orbit with a ground-based missile. This event created more than 3,000 pieces of debris larger than 10 cm and an estimated 150,000 larger than one centimeter (cm). The figure for smaller, undetectable debris is likely much larger. This debris cloud has remained in orbit since the test, severely polluting the region surrounding the destroyed satellite's former orbit and posing a danger to other satellites in the vicinity (Hildreth & Arnold, 2014). T.S. Kelso of the Center for Space Standards and Innovation in Colorado Springs, and Vasiliy Yurasov and Andrey Nazarenko at the Institute for Precision Instrument Engineering in Moscow believe some of this debris hit a small Russian satellite in 2013 (David, 2013). In 2009, an accidental collision occurred between an inactive Russian Cosmos satellite and an active communications satellite belonging to US-owned Iridium. This accident produced another 2,100 pieces of debris larger than 10 cm and many tens of thousands of smaller pieces. Taken together, the Chinese ASAT test and the Iridium-Cosmos collision are estimated to have increased the debris population by more than a third and essentially wiped out 20 years of progress on controlling debris growth through the IADC/UN mitigation guidelines (Hildreth & Arnold, 2014).

In early 2015, there was another incident when a 20-year-old US Air Force weather satellite experienced a temperature spike that caused its fuel tank to explode. The explosion destroyed the satellite and created 40 large pieces of debris that could remain in orbit for decades (Clark, 2015). These incidents do not just illustrate the reality of the danger orbital debris poses, they also indicate that the clock is ticking for stakeholders in the space environment to develop a workable set of solutions to the problem. Despite this realization, debate continues to rage and broadly-agreed upon solutions remain elusive.

b. Technical and Policy Issues for Addressing Existing Debris

Addressing the existing debris population is a multifaceted problem that lacks easy solutions. While technically challenging, it is also fraught with political and economic difficulties that have thus far hindered any attempts to take concrete action on the issue. On the technical side, solutions that have been proposed over the years include (1) the bulk collection of small pieces of debris using automated spacecraft; (2) hitting pieces of debris with directed energy from ground-based systems or space-based lasers to slow their velocity, thereby causing them to fall back into the atmosphere; (3) deploying large "trash tenders" capable of removing defunct satellites and large pieces of debris; and (4) attaching long tethers to upper stage rocket boosters that are electrically charged in order to interact with the Earth's magnetic field and pull the boosters down into the atmosphere (Kaplan, 2009). An additional proposal calls for tethers to be built as compact, independent spacecraft that would be launched as secondary payloads, much like CubeSats, and then deployed in orbit where they would expand and propel themselves via their interaction with the Earth's magnetic field to remove pieces of debris in a variety of orbits. Such craft, called Electro Dynamic Debris Eliminators (EDDEs), would essentially serve as persistent debris taxis capable of removing thousands of tons of debris from LEO without the need for their own fuel (Anzaldua & Dunlop, 2014).

While each of the above technical options has some merit and could begin testing and implementation in relatively short order, technology is only one part of the solution. Political, economic, and social interests must align in order for policies to be created and implemented. Policies that mitigate the addition of new debris to the orbital environment have been relatively easy to implement because they are not prohibitively expensive and can be done on a voluntary, individual basis. For existing debris, the task of policy creation and adoption is much more difficult.

The most seemingly obvious solution on the policy front involves the creation of a new treaty or UN resolution that fills the gaps left by the OST and requires states to enforce compliance on space activities within their borders based on their responsibilities under the OST. Unfortunately, this solution has been proposed or attempted a number of times without success. For example, since the 1980s, the UN has annually approved a resolution on the Prevention of an Arms Race in Outer Space (PAROS) only to be blocked by consistent opposition from the United States and other nations that feel that PAROS limits their right to defensive action in space. Despite overwhelming support in the UN community, PAROS cannot get past the UN Conference on Disarmament (CD), where consensus rules mean a single nation can block an item from getting onto the agenda (Moltz, 2014). In 2008, China and Russia jointly submitted a draft treaty called the Prevention of the Placement of Weapons in Outer Space (PPWT) to the CD citing the "peaceful purposes" language of the OST. The US and other nations criticized the draft and have thus far rejected it, citing vague language concerning verification and whether or not ground-based weapons would be banned as well as space-based weapons. Additionally, many critics doubted the sincerity of the proposal and noted that it made no mention of the IADC guidelines that had been adopted by the UN only a year before (Su, 2010). The roadblocks these formal attempts at regulation encountered within the UN illustrate the difficulty of navigating states' concerns about their national security in the space domain.

Other international efforts, including those dealing with debris issues, have met with a bit more success. In 2008, the UN Committee on the Peaceful Uses of Outer Space (UN COPUOS[1]), the parent organization of UNOOSA, agreed to form a Working Group on Space Sustainability. This group meets separately from the main UN COPUOS meetings to draft reports and sets of best practice guidelines to ensure space sustainability. The group includes panels of experts dealing with debris, frequency interference, and other space operations issues, and includes input from NGOs and private sector firms (Williamson, 2012). Progress has also been made on an initiative led by Russia to form a Group of Governmental Experts to address the prevention of an arms race and encourage the sustainable use of outer space. The Group of Experts was charged to develop a set of transparency and confidence-building mechanisms (TCBMs) for outer space. This approach is based on similar efforts that had some success in addressing various arms control issues (Williamson, 2012). The Group of Experts (GOE) was endorsed by the UN and created with 15 members, including all five members of the Security Council. The Group delivered a report to the Secretary General in 2013 that endorsed enhanced international collaboration on space sustainability issues, including debris cleanup and mitigation (Moltz, 2014).

There has also been progress in the last few years on an effort led by the European Union to develop a Code of Conduct (CoC) for Outer Space Activities. The intent of the CoC is to develop a set of best practices that would "enhance the security, safety and sustainability of all outer space activities" (European Union, 2014). Some of its key stipulations include (1) the freedom for all states to access, explore, and exploit space for peaceful purposes without interference; (2) the right to individual or collective self-defense as codified in the UN Charter; (3) the responsibility of states to take all appropriate measures and cooperate in good faith to prevent harmful interference in outer space activities; and (4) the responsibility of states to prevent outer space from becoming an area of conflict (European Union, 2014). The draft CoC addresses the mitigation of debris as well as radio interference and endorses the GOE report mentioned previously. Like the IADC debris mitigation guidelines, the CoC would be voluntary in nature and aims to establish norms of behavior through adoption by major space powers that can influence the behavior of smaller actors and newcomers. The initial draft CoC was received somewhat coldly, in part because early discussions regarding its language left out some emerging space powers like India thanks to oversights on the part of the negotiators. However, it has since gained traction and was officially endorsed by the United States in 2012. It has gone through several revisions since (Williamson, 2012; European Union, 2014).

While the attempts at policy action through international governmental organizations have met with some success, they are not the only part of the equation. Recently, proposals have appeared in the private sector and civil society that would address the existing debris population. Importantly, these proposals tend to consider one major issue that the political proposals outlined above do not: costs.

Typically, the proposals from the private sector and non-state actors involve setting up some sort of market for the removal of existing debris and/or a launch fee on all new launches. The debris removal markets could operate somewhat similarly to carbon markets that already proposed and implemented on Earth to address carbon emissions (Adilov, et al., 2013; Hanson, 2014).

[1] UN COPUOS is the committee created by the UN General Assembly to deal with international cooperation on the peaceful uses of outer space. It is an ad-hoc committee that currently consists of 77-member nations and several NGOs and international organizations with observer status. UNOOSA serves as the committee's secretariat.

The launch fees would function as a Pigovian tax, or "use tax" (e.g., parking fees or toll roads). These fees would be collected and used to fund the implementation of one or more of the technical options proposed for the removal of debris, for example, the EDDEs. One option under these plans is to have governments provide seed funding to start the program proportional to the amount of existing debris their space activities have contributed to the orbital environment (Adilov et al., 2013). However, this would place much of the burden on Russia and the US, and they may be unwilling to foot such a large bill.

A variation of the above plan is to institute a bounty system for the removal of defunct satellites and large pieces of debris (Anzaldua & Dunlop, 2014). The idea here is to incentivize private firms to develop debris removal technologies. Launch fees would be collected by an appropriate international institution such as the International Telecommunications Satellite Organization (ITSO[2]) and awarded as bounties by the collecting institution only in the case of a successful removal. An alternative option is to have the launch fees serve as partially refundable deposits. Upon removal of a launched spacecraft from orbit, the refundable portion of the launch fee would be awarded to the launching company (Anzaldua & Dunlop, 2014). Gaining global agreement on a proposal such as this may be difficult, so another alternative might be to implement such systems at the national level first in the hopes of influencing others to follow along. Such a system would initially have to be limited to objects owned by the state in question or its companies, since all objects, even debris, are the property and responsibility of launching states under the Outer Space Treaty (OST). Proper protocols would be necessary to allow states and companies to approach and interact with objects owned by others.

Each of the aforementioned technical and policy solutions have their merits and it is likely that the future sustainability of space operations will depend on more than one of them being implemented. However, beyond the cost hurdles that lie in their path there are also some technical and political issues that must be addressed. Until they are, real progress on the removal of existing debris cannot begin in earnest.

The first major issue is the sharing of data among all relevant space actors. Currently, the US and Russia have the best systems in the world for tracking space debris, or maintaining "Space Situational Awareness" (SSA), but they have difficulty tracking objects smaller than ten cm and do not cover the entire orbital environment. Further, these systems are largely run by the militaries of each nation, which are understandably skeptical of publicizing information that might be critical to their operations. The US and its allies are working to improve their SSA capabilities; but in the end, radar data is limited by the system's technical specifications and geographical location. To achieve maximum accuracy in terms of tracking and collision prediction, it would be best to have access to the telemetry data that specific spacecraft operators have about their spacecraft (Moltz, 2014; Loomis, 2015).

The private sector and civil society have begun to take some action on their own to improve SSA capabilities. For example, the Space Data Association (SDA) was recently formed by major satellite operators to facilitate the sharing of telemetry information. This could perhaps signal the beginning of better cooperation within the private sector and civil society, and perhaps reduce some of the risks posed by orbital debris by providing more accurate information for operators to

[2] The ITSO is the modern evolution of Intelsat, an intergovernmental consortium formed in 1964 to manage satellites providing international broadcast services. It was privatized in 2001 and currently consists of 149-member states operating 52 satellites, one of the largest constellations in use.

use to avoid collisions. Such cooperation could also encourage government actors to cooperate more with the private sector in developing solutions and regulations (Williamson, 2012; SDA, 2015).

In addition to the need to improve SSA capabilities and collaboration, there are issues concerning the liability convention established by the OST that were hinted at earlier. Under the OST, even a defunct satellite or piece of debris is the property and responsibility of the nation that launched it. Approaching or interfering with a debris object launched by another entity could be viewed as an act of aggression that could snowball into a major international incident. Even if a state willingly consented to the removal of one of its satellites by another state or private company, the original state would remain liable in the case of an accident during the removal process (Hildreth & Arnold, 2014). It is doubtful that states that are unwilling or unable to finance and carry out removal on their own would be inclined to take on this sort of additional risk without new regulations.

Lastly, there are also issues related to the dual-use potential of several debris removal technologies. For example, high-powered lasers that could be used to slow pieces of debris until they fall back into the atmosphere could potentially be used to damage optical equipment on an adversary's reconnaissance satellites. Likewise, spacecraft capable of approaching and grabbing defunct satellites or large pieces of debris could also be used to disable active ones owned by another nation. Development or deployment of such technologies by any single nation on a unilateral basis is likely to raise suspicion from its geopolitical rivals (Martin, 2015).

V. Application of Ostrom's Principles to Space

As the preceding sections indicate, space debris is a collective problem that must be addressed through collective action. Otherwise, the likelihood of a "tragedy of the commons" scenario unfolding via the Kessler Syndrome only increases as time goes on. Nobel Prize Winner Elinor Ostrom's (1990) landmark study of CPR management systems at the local and regional level proved that Hardin's choice between full privatization and government takeover of the commons was not the only option for sustainable governance. However, her findings must be modified to be applicable for global commons such as outer space. Recently, scholars such as the Secure World Foundation's Brian Weeden, Tiffany Chow, and others have made some initial attempts at adapting Ostrom's framework to space (Stern, 2011; Weeden & Chow, 2012; Johnson-Freese and Weeden, 2012; Chow & Weeden, 2013). A review of their findings will now commence by reviewing Ostrom's original principles in their original order. Later, this analysis will help create new criteria for sustainability.

a. Clearly Defined Boundaries (#1)

The studies by Weeden, Chow, and Johnson-Freese note that there are currently no legally defined boundaries for outer space. Additionally, they note that treating the entirety of outer space as a single commons is problematic because this definition would have to extend to the whole universe. As a solution, they recommend breaking outer space down into more manageable commons at smaller scales. For example, Earth's orbital environment can be treated as a CPR, while the Moon might be treated as another (Weeden & Chow, 2012; Johnson-Freese & Weeden, 2012).

However, even when broken down in this manner, defining boundaries for Earth orbit is difficult. Scientists tend to consider the Karman Line at 100 km as the general boundary between space and the atmosphere, but this is not a uniform definition. In the US, for example, individuals are considered astronauts if they fly higher than 80 km. Likewise, there is no legally defined boundary for the upper limit of Earth orbit. Currently most satellites orbit under 40,000 km, but a few go as far out as 200,000 km; and eventually, regular activities in Earth orbit may extend all the way to the Moon (Johnson-Freese & Weeden, 2012).

Clarifying Earth's orbital boundaries is more important from a regulatory and operational standpoint than a technical one. A primary concern here is developing an internationally recognized definition for where national airspace and aviation legal regimes end and where space governance takes over. Craft intended for space tourism and other operations expected to begin soon are problematic here because they cross into space without orbiting the Earth, yet begin and end their flights much like a normal aircraft would. One recent suggestion by Professor Henry Hertzfeld of George Washington University calls for an altitude near the Karman Line to be designated as the boundary of national airspace (Hertzfeld, 2011). Objects that fly no higher than this line would retain their current "sub-orbital" classification and be subject to national aviation regulations. Objects that fly higher than this but lack enough velocity to stay in orbit would be placed in a new "non-orbital" classification subject to global space governance (Weeden & Chow, 2012). However, objects that would fall under this new classification include ballistic missiles and other objects that many nations consider integral to their national defense, which makes the idea of ceding sovereignty over decisions to use such technologies a tough sell to many governments.

The studies also recognize the need to identify all stakeholders in the orbital environment and take note of their rights, responsibilities, and capabilities when attempting to define boundaries for it. They identify three groups: (1) "spacefaring" states with the full spectrum of operational capabilities; (2) "space capable" states who operate satellites but may not be able to build or launch them independently; and (3) "space users," covering public and private organizations and individuals who use space services and data (Weeden & Chow, 2012; Johnson-Freese & Weeden, 2012). This breakdown of stakeholders is a good start, but as noted earlier, each of these groups is incredibly diverse and not uniform in their motivations and concerns (e.g., spacefaring nations can be developed or developing). Defining acceptable boundaries for the orbital environment will require careful coordination among the various actors within these groups and overlapping sub-groups.

b. Congruence Between Appropriation and Provision Rules and Local Conditions (#2)

This principle stipulates that the governance structure for a CPR must be specifically tailored toward that CPR and the conditions surrounding its use, rather than copied directly from another CPR management scenario. Weeden and Chow (2012) note that this is more difficult than it sounds, and point out the tendency to use maritime governance as a basis for space governance. As noted earlier, aviation law is also often used as a model when drafting potential policies for space. While this may make sense on the surface, the physics of spaceflight do not lend themselves to the same regulations as maritime operations or aviation. For example, requiring a satellite to travel at a certain speed to avoid collisions might sound ideal, but because a satellite's orbit is a function of its velocity counteracting Earth's gravity, any change in speed will result in a change in orbit. A further complication is that military space activities are handled by air forces in many countries, which has led to a situation in which many national space governance structures do not fit well with the realities of space operations (Weeden & Chow, 2012). Policymakers will have to create rules and institutions specifically geared toward the social and political contexts of space sustainability in order to effectively address the orbital debris problem.

c. Collective-Choice Arrangements (#3)

This principle calls for the inclusion of all stakeholders when creating and modifying rules for a CPR. Weeden and Johnson-Freese (2012) note that many of the institutions for space governance exist in the UN system and do not fully meet this requirement. For example, the CD handles military matters related to space and operates by consensus, which blocks progress if any one actor does not agree, as noted earlier. UN COPUOS handles civil space matters and also operates under consensus procedures and their inherent drawbacks. Further, both the CD and UN COPUOS only give real power to states. NGOs can apply for permanent observer status, but do not receive vote privileges. Commercial entities are excluded entirely (Johnson-Freese & Weeden, 2012).

Another forum for space governance within the UN system is the International Telecommunication Union (ITU). The ITU coordinates the radio frequency spectrum used by satellite operators and is also in charge of distributing the limited number of slots available in GEO due to its limited size. The ITU has done so well in this role that some believe it may have prevented conflict from breaking out between states looking to capitalize on the limited availability of frequencies and orbital slots (Moltz, 2014). The ITU includes NGOs and commercial actors as a part of its governance processes and does not operate by consensus. However, it does not have enforcement powers, which hinders some of the effectiveness of its collective nature. Another option for collective decision-making is the establishment of norms through soft law, or customary international law, created by state practices. This is what the IADC guidelines and proposed Code of Conduct attempt to do, but they take time and considerable negotiation to implement, and beyond that, even more time for practices developed around the guidelines to be widely accepted (Weeden & Chow, 2012).

Ultimately, Weeden and his colleagues determined that space needs an open forum that includes all groups of stakeholders, but does not operate on a consensus basis. This is necessary to avoid gridlock. However, it will be difficult because it will require established space powers giving up some of their freedom of action, which they have thus far adamantly opposed (Johnson-Freese & Weeden, 2012; Weeden & Chow, 2012).

d. Monitoring (#4)

This principle stipulates that trusted monitors that are accountable to the stakeholders actively audit the CPR's conditions and the behavior of the stakeholders. In terms of the space domain and orbital debris, this is the SSA issue noted earlier. Accurate and complete information on this front is critical to achieving sustainability in Earth orbit, but as Weeden and his colleagues note, there are significant roadblocks here concerning critical national security information and corporate proprietary data. They conclude that convincing states and corporations that sharing this information via an international monitoring organization is in their best interest may simply be a matter of gaining their trust. The Space Data Association seems to be a step in this direction on the commercial side (Johnson-Freese & Weeden, 2012).

e. Graduated Sanctions (#5)

This principle relates to the issues related to the enforcement of CPR regulations. Ostrom stipulates that appropriators be assessed graduated penalties based on the seriousness and context of their violation either by other stakeholders or by officials held accountable to them. One-time and/or minor violators are punished to a small extent, but not so badly that they are forced out of the CPR regime or choose to leave on their own. This works because stakeholders may not be willing to submit to strict penalty systems out of fear that it will limit their freedom of action or that adherence might become politically untenable at some point in the future. An example of this would be public reprimanding of an actor that commits a violation, thereby building public pressure on them to change their behavior.

The reaction to China's 2007 ASAT test is a demonstration of how this could work in space. The test was carried out without warning to the public and drew condemnation from established space actors through diplomatic and public channels. This "scolding" was followed in 2008 by a US test that destroyed a defunct American satellite that was already falling back into the atmosphere and was believed to still be carrying some of its toxic fuel. The test was carried out with advance notice to other countries, and the debris created quickly fell back into the atmosphere as opposed to creating further hazards in orbit. A second Chinese test in 2010 was carried out in similar fashion, with advance warnings given to other states and minimal debris in the aftermath. Weeden and his colleagues conclude that this sort of flexible enforcement is a viable way to establish and enforce norms of behavior that can lead to space sustainability better than harsher penalty systems that may actually encourage conflict and non-compliance (Weeden & Chow, 2012).

f. Conflict Resolution Mechanisms (#6)

This principle stipulates that stakeholders must have access to quick, low-cost arenas that they can use to resolve conflicts relating to the CPR. One mechanism that exists for space is the Liability Convention established under the OST in 1971, which allows affected states to claim damages from launching states resulting from the latter's space activities (Liability Convention, 1971). However, this requires the use of formal diplomatic channels, which would rely on the broader diplomatic relationship between the affected states. This could be problematic if the states involved have hostile relations, or disagree on other key issues that could affect negotiations under the Liability Convention. The Liability Convention has only been invoked once in 1978 after a Soviet satellite crashed in Canada spreading radiation from its reactor over a wide area (Moltz, 2014; Weeden & Chow, 2012). However, the Convention's mechanisms were not actually used. Instead the Soviets agreed to pay $3 million in damages via a separate agreement with Canada.

There are other possibilities as well. The ITU also has protocols for disputes between states over electromagnetic interference or GEO orbital slots. However, only bilateral, non-binding negotiations have been pursued so far. Another option is The Permanent Court of Arbitration (PCA) in The Hague, which recently created draft rules for arbitration proceedings related to space activities. The PCA was created in 1899 and is one of the oldest and most respected international dispute resolution institutions in the world. It has the authority to handle disputes between states, private parties, NGOs, and even between companies and states they reside in (Weeden & Chow, 2012). Weeden, Chow, and Johnson-Freese are unclear about what additional steps, if any, need to be taken to bring space governance into line with this principle. However, it seems creating fora or modifying existing ones to be more inclusive would be a wise strategy.

g. Recognition of Rights to Organize & Nested Enterprises (#7 & #8)

Ostrom's principle of recognition of the rights of appropriators to organize stipulates that stakeholders be allowed to set up their own rules and institutions for managing a CPR without undue interference from outside officials. At the global scale, this falls under Ostrom's final principle: the creation of nested enterprises. This means rules at one level of governance must be reflected in the rules enforced at other levels. For space, this is already the case to some extent. The OST designates states as the responsible parties for enforcing space governance, and they do so through national space regulations. However, Weeden and Chow (2012) point out that not all states regulate in the same way, and some states lack the technical or other requirements to govern properly, leading to situations in which companies and other space actors can seek "flags of convenience" by launching from states that have the least control and fewest regulations. Additionally, the development and rapid adoption of CubeSats discussed earlier presents a new complication that states may not have fully considered. They propose an awareness campaign that would help states understand their responsibilities and offer guidance on how to develop the necessary national space policies and regulatory mechanisms (Weeden & Chow, 2012). This task would have to be handled by an international organization with an appropriate amount of resources and support.

h. Additional Principles for Commons Governance and Emerging Technologies

Paul Stern of the US National Research Council also attempted to adapt Ostrom's framework to questions of global CPRs and the management of risks for emerging technologies, which he found bear some similarities to CPR issues. He also found that global commons have significantly greater requirements for information, dealing with conflicts, and allowing for adaptation in governance structures, leading him to develop four additional principles for global CPRs (Stern, 2011). At this point, Stern's additional principles require examination so they can help develop new criteria proposed here.

Stern's first principle is to *invest in science to understand the resource and its interactions with users that are affected by its use*. This is critical because global CPRs are often characterized by inadequate knowledge about the resource system and its state of degradation. Investing in science and knowledge sharing improves understanding of the CPR so that stakeholders can know what to monitor and sanction (Stern, 2011). This principle seems to apply well to the orbital environment given the gaps mentioned earlier in global and national SSA capabilities. Doing more to fulfill it would allow for the creation of a better governance system in anticipation of increased use of space in the coming decades. For example, more and better detection equipment can help catalog and track the debris population, and improved sharing of this data can help reduce the risk of accidental collisions.

The second additional principle Stern proposes is related to the first: *Integrate scientific analysis with broadly based deliberation*. This principle addresses the existence of uncertainty in larger CPR systems and the need to share information and solutions with all stakeholder groups as found in Ostrom's framework. When uncertainty exists, actors may behave under unduly optimistic assumptions leading to increased risk and degradation of the CPR. In addition, parties with differing interests can produce their own versions of information regarding the CPR, which leads to distrust and thereby hinders effective governance (Stern, 2011). This principle also seems to apply well to space due to the distrust between national militaries noted earlier and the variety of private stakeholders that hold proprietary information about their spacecraft in orbit. Additionally, studies have noted the uncertainty that exists with mathematical models used to make predictions about the orbital debris population (Matney, 2005). Greater deliberation and new data could help reduce uncertainties about the debris population and improve orbital debris models. More importantly, they will provide a more accurate picture of the current state of the orbital environment, including the positions and behaviors of debris objects within it. Producing such a picture is a necessary step to ensuring the safety of space operations, much like gathering and sharing radar and other tracking data is important for the safety of commercial aviation and shipping. Without it, stakeholders in the space environment are flying blind, at least partially.

Stern's third additional principle is to *plan for institutional adaptation and change (iterative risk management)*. This principle calls for flexibility in a CPR governance system as uncertainties are addressed, new science is developed, and additional technological solutions present themselves. Governance institutions must be able to learn by incorporating new data from the field rather than simply following established protocols (Stern, 2011). Given the highly technical nature of the orbital debris problem and several of the solutions proposed for it, as well as the gaps in knowledge noted earlier, this principle also seems to apply.

The fourth new principle Stern proposed is to *engage in a variety of institutional forms*. This expands on Ostrom's principle of nested enterprises by stipulating the need for a variety of different *kinds* of institutions to go along with different *levels* of governance. This allows for experimentation with different types of solutions and institutional forms to address the CPR in question (Stern, 2011). This sort of institutional variety is a keystone of polycentric governance, which Ostrom and others have recently identified as a promising approach to CPR issues (e.g., Ostrom, 2010; Shackelford, 2014). This principle has some merit for the orbital environment as well, since there is already some variation in institutional forms to go along with international and national layers of space governance. For example, the manner in which the ITU administers GEO orbital slots and frequency allocations differs from how the CD or UN COPUOS address LEO.

Stern also found that emerging technologies bear some resemblance to CPRs because they often create common-pool hazards, which can affect groups and individuals not actively involved in their use. These common-pool hazards include externalities such as the introduction of toxic substances into the environment or invasive organisms spreading to new ecosystems. Stern concludes that CPR management principles can be useful in addressing these risks (Stern, 2011). In the space environment's case, the common-pool hazards are the degradation of the orbital environment and the threat this poses to space operations and public goods and services that depend on them. As private companies and other non-governmental actors pursue human spaceflight, there are also increasing hazards for life on Earth. In light of these realities, space can be classified as both a CPR and a frontier of emerging technology.

VI. A Brief Overview of Other Global CPR and Emerging Technology Issues

In the previous sections, this author explored the nature of the space debris issue and the history of space governance and further laid out the case for treating them as a global commons and CPR management issue. Additionally, it was established that space can be looked at as an issue of emerging technology, which has inherent common-pool risks that overlap with CPR concerns. From this, one can conclude that space governance, especially concerning the orbital environment, can benefit from the application of Ostrom's principles for CPR management so long as they are modified appropriately. For guidance on how this might be accomplished, it is useful to take a brief look at attempts to manage other global commons and what lessons they can offer for the orbital environment.

a. <u>The Oceans</u>

The oceans are the oldest recognized global commons. Beginning with the advent of sailing technologies that allowed commerce and transit to occur over long distances, the high seas have been treated as such in practice, if not in law, for centuries. The only exception to this has been a narrow band of territorial waters along coastlines, and more recently the recognition of national exclusive economic zones (EEZs) extending out to 200 nautical miles. This long-standing commons status partially stems from the fact that the ability to freely access the high seas is critical to the security and economic interests of national governments and their militaries. Even when EEZs were established in the 1980s, a compromise was reached ensuring the rights of passage for warships and submarines through dozens of straits for peaceful transit (Vogler, 2012).

Today the oceans are governed by the third UN Convention on the Law of the Sea (UNCLOS III), which was created in 1982 after negotiations that began nearly a decade earlier. The treaty finally entered into force after another decade of delays in 1994. UNCLOS III redefined the boundaries of national territorial waters, including the creation of EEZs, while also establishing general obligations for nations to protect the marine environment and to allow freedom of navigation and scientific research on the high seas (UNCLOS III, 1982). In line with Hardin's theory of enclosure by the state, the creation of EEZs and extension of national sovereignty over other parts of the oceans was intended to help protect CPRs such as fisheries that were threatened by overuse due to increased global demand and advances in extractive technologies. However, this strategy has not worked as planned, as the continued degradation of many fishing grounds and other marine sources located within territorial waters indicate (Vogler, 2012).

A major issue that arose with UNCLOS III is the Common Heritage of Mankind (CHM) principle that was noted earlier in regards to the 1979 Moon Treaty. Given that negotiations for both treaties began within a decade of each other, this is perhaps unsurprising. UNCLOS III applied the CHM principle to the seabed and created the International Seabed Authority to govern the exploitation and distribution of mineral resources mined from the ocean floor, which technological and business trends at the time indicated might soon become feasible. Additionally, this organization would have facilitated mandatory technology transfers to developing countries, and would have assessed pollution fees on profits developing countries made from the exploitation of resources on the ocean floor (Ehrenfreund et al., 2013). Disagreement over these provisions dragged on until a compromise was reached in 1994 that reduced these measures, leading to the ratification of the treaty and the birth of the International Seabed Authority that same year. However, no undersea mining has taken place despite the Seabed Authority's best efforts, and the US Senate routinely refuses to ratify the treaty despite the encouragement of multiple presidential administrations and observance of many of its principles in practice by the US government (Vogler, 2012).

The story of UNCLOS III offers some examples of what to try and what to avoid for policymakers seeking to improve space governance. For example, attempts to fully entrust states with managing the sustainability of marine CPRs by extending their sovereignty over larger parts of the ocean have produced mixed results. On the other hand, the long-standing recognition of the high seas as a global commons outside the jurisdiction of individual states has allowed the world's oceans to become the highways of modern society, carrying some ninety percent of global trade (International Maritime Organization, 2015). The orbital environment does not produce quite this much economic value for the world, but it does play an increasingly significant role in world affairs and seems like it could benefit from a similar delineation of sovereign boundaries. Such a breakdown would allow for institutional and policy experimentation at national, regional, and local levels that would satisfy the modifications to Ostrom's principles put forth by Weeden, Stern, and others. From this process of experimentation, best practices and norms can be established that can help lead the way toward cleaning up existing debris and achieving long term sustainability in Earth orbit.

b. <u>The Antarctic</u>

Like space governance, Antarctic governance developed in the context of the Cold War. As technology made regular exploration, study, and exploitation of the continent more realistic, nations began to stake territorial and resource claims to it in the 1950s. However, due to Cold War tensions and fears of conflict, these claims were nullified with the establishment of commons status for Antarctica in 1959 via the Antarctic Treaty (Vogler, 2012). The Antarctic Treaty was initially signed by twelve nations and stipulated that the continent only be used for peaceful scientific purposes. It also established information sharing and dispute resolution protocols, as well as consultative meetings, amendment provisions, and the Scientific Committee on Antarctic Research, which operates as part of the International Council for Science (Ehrenfreund et al., 2013).

The Antarctic Treaty has evolved since its inception and is now referred to in conjunction with its many amendments as the Antarctic Treaty System (ATS). The amendments to the ATS over the years addressed a wide range of topics, including biota and ecosystem conservation, waste management and pollution control, and the designation of specially managed and protected areas (Ehrenfreund et al., 2013). Another similarity the ATS shares with the OST is the designation of signatory states as the responsible and liable parties when it comes to regulating activities on the continent. Tourism, which has become somewhat popular, is managed by an industry-created group known as the International Association of Antarctica Tour Operations. This association has developed a voluntary set of best practices over its decades of existence and works closely with national governments for access to their research bases and outposts. Interestingly, in the late 1980s, an attempt was made to set up an international organization called the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) to manage and tax the mining of Antarctic resources for nonscientific purposes, similar to what was attempted under UNCLOS III for the sea floor. However, the CRAMRA amendment was rejected by the states party to the ATS, and at the 1991 Antarctic Treaty Conference in Madrid they approved a 50-year moratorium on nonscientific mining (Ehrenfreund et al., 2013). In this case, the primary reason cited by some states for rejecting the international mining organization was environmental. They feared that mining technology had not advanced far enough to guarantee the protection of the Antarctic environment if allowed to operate on the continent. However, there were also fears that such an organization would open up the continent to subsidized mining operations that would undercut those of leading Antarctic states such as Australia (Blay & Tsamenyi, 1990).

The ATS is largely considered a success in terms of managing a global commons and has enjoyed a high amount of cooperation among the 48 states that are now members of the treaty. This treaty regime has been successful because the rules represent what the states party to it are willing to accept and do not attempt to alter their behavior to any drastic extent (Vogler, 2012). Additionally, the ATS requires that a state actively pursue scientific research in Antarctica to be eligible to participate in the modification process. Countries that do not actively participate in research on the continent are thus forbidden from having a say in its governance. In a sense, the ATS itself functions as an incentive for countries to make investments in the Antarctic commons in order to participate in its governance. (Ehrenfreund et al., 2013).

The ATS provides some useful examples for successful governance that might be applicable to the orbital environment and space debris. For example, the recognition of state sovereignty as a primary concern when creating the regime rules ensures that the commons are governed by a system that the most powerful group of stakeholders—national governments—will be willing to participate in. Failure to do this in other attempts at commons governance, like the Moon Treaty, have resulted in the system being abandoned and ignored en masse. The ATS's requirement for research participation is also an interesting example of how to encourage stakeholder investment in the regime and negate the "free rider" problem often associated with CPR issues. Nations, corporations, and other organizations are more likely to work toward preserving an environment during its development when they have made investments of time and money, and presumably would be less likely to be obstructive in the manner seen in the CD during attempts to negotiate space arms control. It is also noteworthy that the number of actors in the ATS is somewhat small when compared with space and other CPRs, so bringing these lessons to bear on their governance may be more difficult than it seems on the surface. Nevertheless, they provide some helpful insights for this effort to develop criteria for sustainability in the orbital environment.

c. The Atmosphere

Managing the Earth's atmosphere is one of the most well-known and complex CPR problems in global governance today. It covers a wide range of issues from typical pollution and air quality for specific cities and regions to the raging debate over how to address global warming and climate change. As a result, numerous agreements, institutions, and other solutions to governing the Earth's atmosphere have been proposed and attempted.

One of the first attempts to govern the environment at the global level was the UN Environment Program (UNEP), created in 1972. However, the UNEP has been plagued with problems from the beginning that have limited its ability to effectively coordinate action on environmental issues, including those concerning the atmosphere. For example, it was set up as a program rather than a UN specialized agency, and as such is reliant on voluntary contributions for funding. This has resulted in contributions from high energy consuming countries falling far short of what UNEP officials have hoped for in recent decades. Many existing agencies also viewed it as a competitor for influence and funding. Finally, the physical location of its headquarters in Nairobi, Kenya has proved problematic. While successful lobbying and organizing by a large block of developing countries to get the UNEP's headquarters located in the global South can be viewed as a symbolic and moral victory for those interested in social justice, the distance this placed between the program and other major institutions centered around cities like New York and Geneva created many difficulties during the program's attempts to establish itself as the chief orchestrator of global environmental governance (Ivanova, 2010).

As a result of the UNEP's shortcomings, other attempts at addressing atmospheric problems have been pursued since its creation. One well-known example is the United Nations Framework Convention on Climate Change (UNFCCC), which was created at the 1992 Earth Summit in Rio de Janeiro. The UNFCCC is a treaty intended to stabilize the levels of greenhouse gasses in Earth's atmosphere in order to mitigate climate change and global warming. The parties to the treaty meet annually and became famous for the Kyoto Protocol that they adopted in 1997. The Kyoto Protocol set targets for limiting the increase of global temperatures to no more than two degrees Celsius in comparison to preindustrial levels (UNFCCC.int, 2014). Unfortunately, the Kyoto Protocol's emission targets led many important states to view it as a threat to their economies. Chief among them was the United States, which refused to ratify the treaty (Barrett, 1998). Several other nations have abandoned it or reduced their participation in it to date (Guardian, 2011).

Despite the difficulties encountered with top-down approaches like the Kyoto Protocol, there have been successes with alternative forms of governance. For example, the Cities for Climate Protection Program was created with the help of the UNEP to connect city and local governments with each other and with resources that would allow them to introduce their concerns to the conversation about global environmental governance and take action on their own if they wished. By 2004, this program had grown into a transnational network of more than 550 city and local governments interested in taking their own steps toward addressing local concerns related to climate change and environmental conservation, such as increasing municipal energy efficiency or reducing local air pollution. Many of the participating cities have achieved success in meeting their local goals (Betsill & Bulkeley, 2004). Scholars have started to identify grassroots, horizontally organized transnational networks like Cities for Climate Protection as important components of effective governance for complex global issues such as climate change. Incremental steps by smaller actors lead to real impacts at the ground level, which in the aggregate can help establish norms and influence national governments and other actors, resulting in real progress in terms of addressing CPR problems (Betsill & Bulkeley, 2004; Ostrom, 2010).

Another successful example of addressing an atmospheric CPR problem is the Montreal Protocol, which dealt with the degradation of the ozone layer. Scientists began to notice the detrimental effects that Chlorofluorocarbon (CFCs) were having on the Earth's atmosphere in the late 1970s and called for action to address them before degradation of the ozone layer became too extensive. A common claim is that, as knowledge of the problem increased, so did momentum toward a solution among all the stakeholder groups involved (Benedick, 1998; Maxwell & Briscoe, 1997; Parsons, 2003). However, an important aspect of the solution to this CPR problem was the availability of technical alternatives to CFCs for the industries, consumers, and other actors that relied on them for their funding or livelihoods. It was not merely the further study of CFCs and their effects that paved the road to the Montreal Protocol's passing, but also the realization that individuals and organizations could adopt alternatives that would address the problem without disrupting their behavior (Sarewitz et al., 2012). Sarewitz et al. dubbed this sort of solutions-oriented approach the "Sustainability Solutions Agenda" and find it is particularly effective at addressing complex system-level problems such as CFC pollution in the Earth's atmosphere. The reason for the Sustainability Solutions Agenda's effectiveness is that it recognizes that people and organizations develop and use technologies for their own socially constructed reasons. Thus, their views and desires are shaped by their interactions with the technology and its effects on the environment, requiring researchers and policymakers to focus on understanding these interactions to achieve sustainability (Miller et al., 2013).

There are some valuable lessons to take from attempts at atmospheric governance for the development of criteria for sustainability in the orbital environment. To begin, one should recognize that space is complex as are the technologies involved in its exploitation and exploration. Nations and other organizations that pursue such technologies are unlikely to want to drastically change their behavior or give up on significant investments of time and money they have already made to comply with a treaty or the demands of an international institution. The deadlocks in the CD and UN COPUOS concerning space weaponry and the CHM principle are examples of this. What is needed is an approach that more fully and equitably engages all stakeholder groups and focuses on technical alternatives that can address the debris problem in the near term without requiring any one group to sacrifice too much.

Technologies like the EDDEs mentioned earlier are examples that might fit the bill, but they must first be demonstrated before they can be adopted on a wide scale. One option to accelerate the testing and demonstration process is to use the ISS as a test-bed for debris removal technologies. The ISS is well-suited for this role since it carries its own power supply, can handle a variety of scientific and engineering tasks, and already generates approximately 10 tons of waste annually that would be suitable for testing debris mitigation technologies. It is possible some recovered material could actually be recycled or repurposed in orbit too, which would potentially help spur the development of a market around debris removal technologies (Anzaldua & Dunlop, 2014). Further, the ISS already has a cohort of major space nations invested in its use, so garnering their support for a debris-related research and development program aboard the station could be easier to accomplish.

d. <u>The Internet</u>

The Internet is perhaps the most complex global commons and also the newest. As noted earlier, it is also an issue of emerging technology that could be amenable to some of Ostrom's principles as modified by Stern. Each year, the Internet becomes more deeply embedded in the lives of individuals, the operations of governments and businesses, the causes of civil society groups large and small, and the overall functioning of the modern world. Yet despite its undeniable importance to our modern way of life, the Internet is governed in a very ad-hoc, informal manner, particularly when compared to other arenas of global governance. The World Wide Web that is familiar to so many is a virtual commons, existing outside the bounds of any individual state and resistant to their attempts to control it, as many recent incidents of civil unrest have shown (Vogler, 2012; Hussain & Howard, 2013). However, the physical infrastructure upon which the Internet depends – servers, cables, electrical grids, and so on – are the property of governments and corporations, subject to their laws and regulations, and not generally considered part of the commons (Vogler, 2012). This creates an interesting contrast between the open, often anarchic nature of the Internet and its power to shape our society and culture, and the sovereign authority of states that wish to control and shape the Internet for their own benefit and security.

When it comes to governing the virtual commons itself, the Internet is heavily reliant on a series of “multi-stakeholder” (MSH[3]) organizations (Waz & Weiser, 2012). These are organizations such as ICANN, which handles the critical task of distributing domain names on the World Wide Web. Others mostly serve as informal fora for discussion and collaboration. However, some of these fora, such as the ITU’s World Conference on International Telecommunications, are of high importance due to the number of governments, NGOs, firms, and other stakeholders who participate in them. Indeed, the MSHs that govern the Internet are as varied and unique as the Internet itself. In many cases, they operate by means of building “rough consensus” as opposed to formal consensus complete with recorded and potentially politically influenced voting procedures. Consistent with the culture that gave rise to the Internet, many of these groups operate on principles of openness and provide an environment in which best practices can be developed and shared rather than voting on formal rules and regulations (Waz & Weiser, 2012). Some states have tried to organize more formal governance for the Internet under the ITU and the UN, but so far, their efforts have failed. Opponents, including major companies and governments of developed countries, feel that this would stifle the creative power of the Internet which so much of global society relies on (Kleinwachter, 2004).

The Internet provides some good lessons for governance of the space environment as both a global commons and an issue of emerging technology. Like the Internet, space is open to all, but the infrastructure and technology required to access and utilize it are the property of states and corporations, with states held responsible by treaty for all activities originating within their borders. Space also intersects with the Internet through the provision of a number of communications and information services. Space is a national security concern for states, but also a key source of economic activity for companies. For individual citizens around the world, it is a source of services, knowledge, and more. Taken together, all of these factors suggest that a hybrid approach somewhere between the more formal approaches to governance attempted in the past with the atmosphere and oceans along with the more ad-hoc, polycentric regime that governs the Internet may be useful for addressing space debris. This merits examination as the attempt to develop a set of criteria moves forward in the next section.

VII. Developing the Criteria

Before proposing criteria for sustainability in the orbital environment, it would be helpful to revisit the stakeholder groups established earlier and their framings of the orbital debris problem. Whereas Weeden, Chow, and Johnson-Freese used capabilities as the lens through which to view the stakeholders in the space environment, this author’s review categorized them by their relationships to the orbital environment and space technologies along with concerns over their use. This is an important method of analysis since technologies are socially constructed and shaped by human interactions and adaptations to them as scholars have determined (Williams & Edge, 1996; Sarewitz et al., 2012). This social shaping occurs via boundary objects and organizations that pro-

3. It is important to note that though they are related concepts, MSHs and polycentric institutions are not necessarily the same. For example, an international institution that only includes national governments could be described as an MSH, but would not be polycentric. An institution that includes national governments as well as private and civil society groups could be described as both an MSH and a polycentric institution.

vide knowledge, services, and other outputs for society, as has been noted in environmental science, sociology, and other disciplines. Boundary organizations bring users and producers of knowledge together to collaborate in the management of a resource. Boundary objects are pieces of information and other outputs that allow users to interact with their environment, and are often produced by boundary organizations (Guston, 2001; Agrawala et al., 2001). Table 3 illustrates the nature of the broad stakeholder groups identified earlier, their relationships to the space environment, and the boundary organizations and objects that help shape these relationships.

As Table 3, which was developed by this author, shows, while there is significant variance in how certain stakeholder groups frame the space environment and debris problem, there are also some areas of overlap. For example, the private sector, governments, and civil society groups all interact with one another to produce services based on space technologies. GPS systems are one such service. They provide navigational assistance to firms for business purposes, aid NGOs in providing development assistance, and allow militaries to enhance their operational capabilities. All three stakeholder groups share an interest in preserving the space environment and addressing orbital debris to maintain access to GPS services and others like them. This mutual interest in the preservation of the orbital environment is key to developing these new criteria.

Table 3: Stakeholder Framings and Boundary Objects/Organizations

Stakeholder Group	Examples	Framing of Space Environment	Framing of Debris Problem	Boundary Objects/Orgs.
National Governments	• USA, Russia, Europe (developed powers) • India, Brazil, South Africa (developing powers)	• "Contested commons", integral to national security, economic competitiveness • Important for economic/social development, international prestige	• Threat to national security and economic stability • Threat to development, pollution problem created by developed powers (social justice)	• Military and government satellites and tracking info • Aerospace firms • International organizations and NGOs
Private Sector	• Aerospace firms • Banks and financial institutions • Shipping companies	• Critical to profit and business development	• Threat to profits, and could result in serious financial losses • Threat to crew/passenger lives for private space companies	• Civil satellites and services (GPS, communications, etc.) • Military and government tracking info • International organizations and NGOs

Civil Society	• NGOs and international institutions • Universities and research organizations • Individual citizens	• Improves quality of life via services (weather, disaster relief, communications, banking, etc.) • Source of knowledge and education • Employment in space industry and dependent sectors	• Threat to quality of life via loss of services • Threat to use of space for descendants (moral/ethical)	• Internet, cell phones, GPS units, etc. • Government institutions and services • Private firms that provide space-based services

Another useful tool for developing these criteria is the governance triangle. The governance triangle was developed by Abbott and Snidal (2009) to examine the fragmented state of environmental governance, which was touched on briefly earlier. Space governance suffers from a similar type of fragmentation, although it has not yet reached the level seen in environmental governance on Earth. The triangle is organized based on the three broad stakeholder groups that were identified here for the orbital environment and attempts to illustrate the level of collaboration between different governance institutions at the global level. An attempt to adapt the governance triangle to the existing space regime is on the next page.

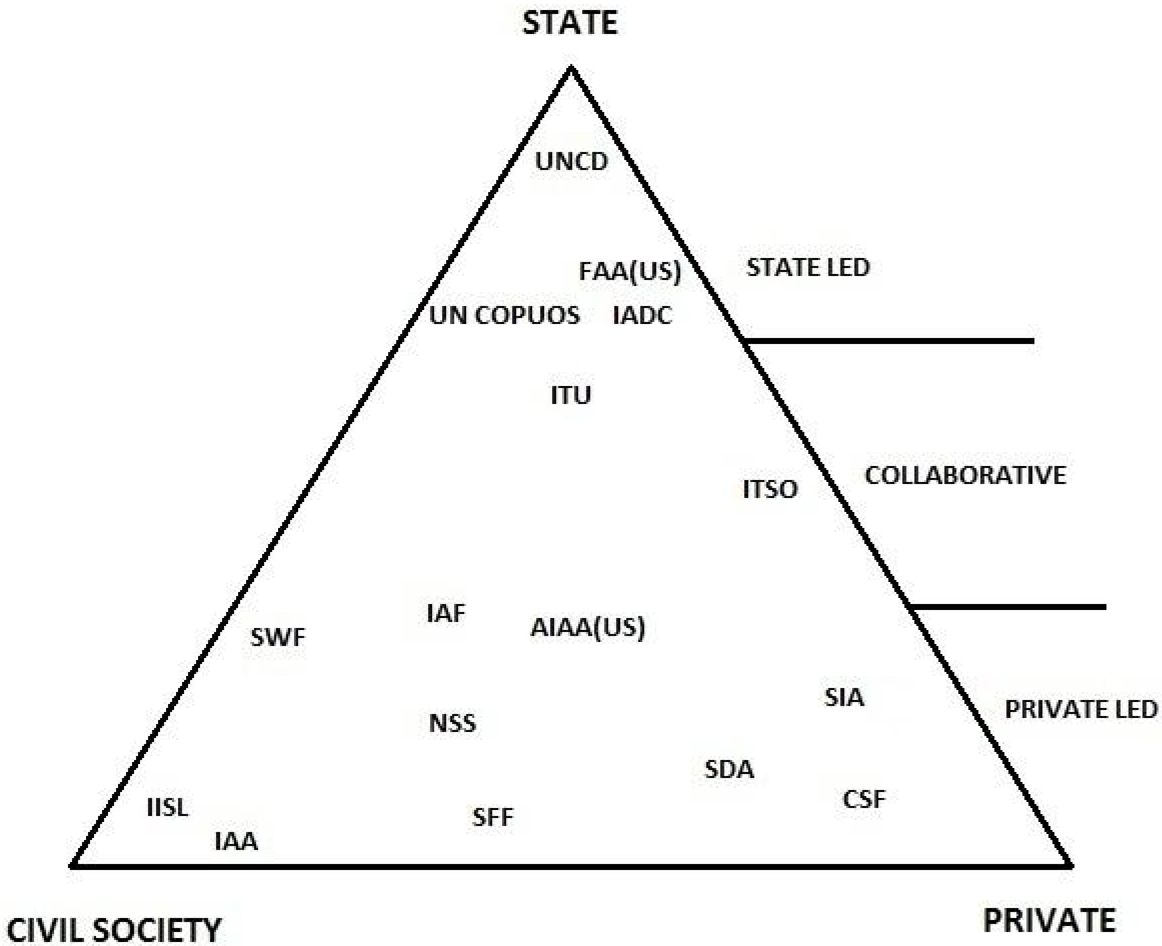

Figure 1: Space Governance Triangle (Adapted from Abbott, 2011, p. 9)

As the triangle above illustrates, organizations attempting to address space governance have been created by all three stakeholder groups and the gaps between some of them remain quite large. State-led groups within the UN dominate, and in the case of the United Nations Committee on Disarmament (UNCD), do not interact with the other two groups. UN COPUOS grants civil society groups an audience, but does not grant them a vote and does not recognize the private sector. Yet, private sector data on their spacecraft and collaboration on debris mitigation is critically important. The ITU is the most collaborative of the state-led groups displayed as it provides a forum for discussion and collaboration between all three sectors, which has been crucial to governance of the radio spectrum and GEO orbital slots. Civil society groups like the Secure World Foundation (SWF), International Astronautical Federation (IAF), and National Space Society (NSS), also provide fora for discussion for state- and private-led groups willing to participate. Outside the ITU and perhaps the IADC, the most noteworthy example of collaboration between states and the private sector is the International Telecommunications Satellite Organization (ITSO), which was originally a state-led organization but is now privately owned. The Space Data

Association (SDA) and Commercial Spaceflight Federation (CSF) could move closer to collaboration as they evolve.

In his application of the triangle to environmental governance, Abbott (2011) concludes that embracing the system's polycentric, fragmented nature through greater orchestration of activities and information sharing is key to bringing about effective governance. Orchestration, as defined by Abbott and Snidal (2010), involves international organizations reaching out to private actors and institutions, collaborating with them, and supporting and shaping their activities. Greater orchestration can help develop stronger networks of public, private, and civil society institutions and establish norms of behavior. This approach can improve governance by addressing both issues of "state failure" caused by the shortcomings of international organizations, and "market failure" problems that occur when the creation of norm-setting institutions is too slow and decentralized (Abbot & Snidal, 2010). Ostrom (2010) comes to a similar conclusion in her analysis of global efforts to address climate change.

Space debris and the orbital environment seem amenable to the same kind of approach. All actors appear to be interested in developing solutions, and efforts to do so are underway within each stakeholder group. Greater orchestration would likely allow for greater effectiveness than any single effort on its own, and certainly allow for more rapid progress. With this in mind, it is now time to propose criteria that any solution must meet in order to have a reasonable chance at both effectiveness as a policy and consensus resulting in political adoption. In so doing, Ostrom's and Stern's principles become the basis from which an attempt is made to simplify them and tailor them into adapted new criteria that specifically address sustainability in the orbital environment.

VIII. Criteria for Sustainability in the Orbital Environment

This section proposes new criteria by this author for sustainability in the orbital environment based on Ostrom's (1990) original principles for CPR management and Stern's (2011) modification of them for the governance of emerging technologies. These criteria synthesize previous efforts to apply Ostrom's principles to the space environment by Weeden, Chow, and Johnson-Freese with lessons learned from other global commons. In so doing, these criteria should help policymakers and stakeholders evaluate potential solutions to the orbital debris problem, and guide them toward policy choices that will ensure the long-term sustainability of the orbital environment.

a. Embrace Polycentrism

As the previous sections of this article demonstrate, global commons are complex systems with many stakeholders that do not qualify for one-size-fits-all solutions. Earth's orbital environment is no different. Therefore, any governance solution must be compatible with the polycentric reality of today's space environment, which will only grow more crowded in the coming years. Nations, corporations, NGOs, and other entities pursue space activities for a variety of purposes. Furthermore, any proposed solution will have to be compatible with the motivations of these groups to make compromises possible in order to be adopted and have a chance at reducing the debris population. Prioritizing one type of solution over another would risk failing to address the entirety of the debris problem and possibly lead to non-compliance or resistance by stakeholders that feel their interests are being ignored or violated. For example, several of the policy solutions examined earlier failed because developed states felt their security was at risk, or because developing states felt social justice was not being served and they were being relegated to a “second class” status. Avoiding such resistance requires including a multitude of voices in debris-related policy discussions and creating or adapting institutions to facilitate them.

Further, polycentrism allows for experimentation with multiple solutions based upon stakeholder preferences. As Ostrom (1990; 2010), Abbot and Snidal (2004), and Betsill and Bulkeley (2004) find, this type of experimentation is necessary for addressing complex CPR problems like space debris. Firms, nations, and others that believe they have a solution should be allowed and even encouraged to pursue it so long as other stakeholders are properly informed and consulted to minimize the chances of unnecessary and unintended conflicts. This addresses Ostrom’s recognition of rights to organize and the need for nested enterprises, and also addresses Stern’s additional requirements to plan for institutional adaptation and change as well as to involve a variety of institutional types. The latter is important because the development of norms, policies, and institutions for a global-scale issue like space debris is guaranteed to be a dynamic process filled with experimentation and adjustment, especially in the early going. Keeping an open mind can avoid stifling potential solutions before they mature, or even worse, committing to unworkable solutions too early.

b. Awareness and Communication

To address a global problem such as space debris, proposed solutions must include methods that improve upon the space situational awareness (SSA) practices currently in use. Lack of complete data is one of the key risk factors associated with space debris, and addressing this gap in knowledge is crucial to fully addressing the problem. Such solutions should include increased investment in SSA technologies along with better sharing of spacecraft data through trusted fora. The registry maintained by UN COPUOS, and the recently formed Space Data Association and the IADC are a good start, but more must be done to coordinate and expand on their efforts. Trust must be built between actors, particularly between major military powers who are often reluctant to share the information they have about the orbital environment. Building this trust may be a slow and incremental process, but doing so will increase the ability of space actors – including militaries themselves – to address the debris threat. The transparency and confidence-building measures (TCBMs) mentioned earlier that the UN Group of Governmental Experts is exploring may provide some ideas here.

Satisfying this criterion will address Ostrom’s monitoring requirement as well as the additional requirements for investment in science and broadly-based deliberation developed by Stern. In essence, it will help create a better system for risk assessment for space actors. This criterion also ties in with the first, since different institutional forms and policies may be necessary to facilitate sharing of civil, commercial, and military SSA information.

c. Responsible Sovereignty

This principle is crucial because of the nature of the international system, which recognizes states as the supreme authority. For this reason, states are held liable for all space activities originating from within their borders under the Outer Space Treaty. States are protective of their satellites because of the importance they hold for national security and economic life, and wary of interference with even defunct spacecraft because of additional liabilities they could incur. Such interference could even be viewed as form of attack. This is where building trust and transparency via TCBMs can be extremely useful.

However, this principle is two-fold. While state sovereignty must be respected in terms of non-interference with spacecraft, states must also be encouraged to accept the fact that they are responsible for the bulk of the existing debris population – especially the oldest and most well-established space powers. Such acknowledgement will also likely play a key role in garnering the participation of developing states such as India, which have concerns about social justice and fairness when it comes to space debris. Nations responsible for the most threatening debris objects must be given options and incentives for addressing the portions of the debris population that belong to them, including enlisting the aid of other states or private companies if they wish in order to save costs. Along with this, it would be useful to establish a boundary where state sovereignty ends and the space commons begin, perhaps along the lines of the suggestion, as noted by Weeden and Chow (2012). This would give states more precise and perhaps more manageable responsibilities if they are otherwise unable to address debris they have placed in orbit many years or decades in the past.

This principle satisfies Ostrom's (1990) requirements for clearly defined boundaries and partially addresses her requirement for dispute resolution mechanisms. It also ties in with the first criterion as it would likely benefit from a variety of institutional forms and practices for facilitation. For example, institutions and practices that focus on the most pressing and/or easily addressable portions of the debris population may build momentum toward state action on larger, more complex and potentially contentious parts of the problem. Such approaches have shown merit on other complex global issues with considerable military and social dimensions (Abbott & Snidal, 2004).

d. <u>Incremental Results</u>

This principle relates to the Sustainability Solutions Agenda touched upon earlier. Space debris is a threat today that demands solutions before it is too late. No single sweeping policy or technical solution is capable of solving the entire problem. Policymakers, scientists, engineers, and others concerned with space sustainability should focus on making progress in small steps rather than taking one giant leap. If a national space agency or a private company wants to test a debris removal technology on their own debris objects, they should be allowed to do so with proper supervision and appropriate consultation with other stakeholders. If another nation wants to implement a launch fee, they should be free to do so. The important point is that solutions that are implemented cannot be disruptive to the space-based services that governments, businesses, and global civil society depend on. As Sarewitz et al (2012) pointed out regarding the Montreal Protocol, stakeholders will readily embrace available solutions to CPR problems given the right data and conditions. In addition, they must be orchestrated through an effective mix of institutions as described in the first criterion to ensure they do not make the problem worse, or interfere with other actors' operations. Cumulatively, these small steps can add up to real progress, which is what the situation requires.

e. Embrace Soft Governance

This principle builds on the lessons of the other global commons and previous attempts to strengthen space governance and address orbital debris. Strict, top-down approaches like the Kyoto Protocol's emission limits and proposals for international regulatory agencies like the International Seabed Authority and the organization proposed under the Moon Treaty have proven largely ineffective at garnering participation from all stakeholders. However, approaches that focus more on the establishment of norms through voluntary, but encouraged adherence have met with more success. Examples include the Cities for Climate Protection Program as well as the IADC guidelines for orbital debris mitigation. The European Union's Code of Conduct could someday be added here.

Soft governance still allows sanctions for behavior that violates norms of sustainability. The more appropriately conducted Chinese ASAT test in 2010, which followed backdoor scolding from the international community and a safer US demonstration after the initial Chinese test in 2007, is an example of these kinds of sanctions in action. Legal proceedings through a well-respected institution like the Permanent Court of Arbitration may work here as well. Corporations and civil society groups are even more amenable to this type of system given their reliance on public image and a desire to avoid controversy.

Further, soft governance requires giving the private sector and civil society as well as established and developing space states fair representation in the proceedings of the governance system. The ITU provides a good example of how this can work in practice at GEO, and could be expanded upon for the remainder of Earth's orbital environment. Internet governance also shows how soft governance can work through the establishment of norms and building of "rough consensus" among multiple stakeholder groups. This practice allows actors willing to take action to do so. In contrast, institutions that rely strictly on consensus like the UNCD are easily derailed when a small group or even a single actor objects. Adherence to this principle satisfies Ostrom's (1990) requirements for collective-choice arrangements, conflict-resolution mechanisms, and graduated sanctions.

IX. Applying the Criteria for Sustainability in the Orbital Environment

To demonstrate the utility of these criteria, they must be applied to a sample set of proposed solutions focusing on the orbital debris problem. Table 4 below performs this task and measures whether or not the solutions listed meet these new criteria. The sections following the table go into more detail about each sample solution's compatibility with these criteria. The sample solutions used were chosen in an attempt to represent the spectrum of solution types (e.g., technical vs. policy) and stakeholder framings of the problem.

Table 4: Application of Criteria to Proposed Solutions

Proposed Solution	Embrace Polycentrism	Awareness & Communication	Responsible Sovereignty	Incremental Results	Soft Governance
Code of Conduct (Policy)	No	Yes, dependent on participation	Yes	Yes, dependent on technical solutions	Yes
PPWT (Policy)	No	Yes, dependent on participation	No	No	No
Bounty Systems (Policy)	Yes	Yes, dependent on participation	Yes, dependent on participation	Yes	Yes
EDDEs (Technical)	N/A	No	Dependent on level of adoption	Yes	N/A
SDA and data sharing orgs. (Mix)	Yes	Yes	Yes	Yes, dependent on technical solutions	Yes

a. <u>The Code of Conduct</u>

The Code of Conduct (Code) proposed by the EU is the first of the solution examples. As Table 4 shows, it does meet a number of this author's criteria, although it is dependent to a certain degree on the number of actors who agree to adopt the Code of Conduct and on the subsequent technical solutions that are implemented. However, when looking at this author's first criterion, polycentrism, the Code falls somewhat short. Although it does seek to include all government stakeholders, it does not directly include stakeholders from the private sector or civil society. These stakeholders could, and likely will, make their concerns known to their national governments, but this does not give them a straightforward avenue to meaningfully participate in the governance process.

When it comes to the other four criteria, the Code rates much better. For example, the Code does provide mechanisms for participating nations to share information and communicate with one another through a Central Point of Contact to be designated upon the Code's adoption. This Central Point of Contact fulfills this author's second criterion for awareness and communication, so long as enough nations participate and share information about their space activities. The Code also meets the criterion for responsible sovereignty through its consultation mechanism, which is designed for use when disputes or concerns arise about specific space objects or activities. The

Code also allows for incremental progress through the establishment of TCBMs such as its information sharing and consultation mechanisms, and could be especially effective in this regard if these TCBMs lead to the adoption of effective technical solutions for debris removal. Lastly, the Code also embraces soft governance through its non-binding, voluntary nature and previously mentioned TCBMs and consultation mechanisms (European Union, 2014). This analysis shows that the Code meets four of this author's five criteria and could be a useful, though it is not an entirely complete policy solution to the orbital debris issue.

b. The PPWT

The Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects is an alternative to the Code of Conduct promoted by Russia and China at the UNCD, as noted earlier. It is a more formal and traditional solution than the Code, and as Table 4 shows, it does not comply with as most of this author's criteria for sustainability in the orbital environment.

Like the Code, the PPWT also fails to embrace polycentrism by only including states in the discussion about governing the space commons. In terms of sovereignty with flexibility and embracing soft governance, the PPWT also falls short. It does not provide for consultation mechanisms. Additionally, due to its nature as a legally binding treaty that bans certain behaviors by sovereign states, it is a form of hard governance. The PPWT does not do much to address the population of existing debris either, since it is focused on the prevention of the future placement of weapons in outer space. As such, it cannot facilitate incremental progress toward solving the space debris problem and preserving the sustainability of the orbital environment in the near term. The PPWT does include provisions for an Executive Committee that would be responsible for disseminating information among treaty signatories, so it is possible that it could lead toward greater SSA for signatories and meet this author's criterion for awareness and communication (Listner & Rajagopalan, 2014).

As this analysis shows, the PPWT, at least in its current form, does not represent a good path forward for addressing the space debris problem. If it were adopted, many stakeholders would be left out, and some, such as the US and its allies, could oppose it outright. Like similar attempts at addressing CPR issues with a formal treaty, the PPWT runs the risk of being ignored by some of the actors whose participation would be critical to its success.

c. Bounty Systems

A bounty system for the removal of certain large debris objects matches well with this author's criteria. Such a system does embrace polycentrism because it engages the private sector and civil society along with national governments. Depending on the exact structure of the system, bounties could be paid out to all three types of organizations if they chose to participate. A bounty system would also require and have to facilitate the sharing of SSA information among its participants in order to work properly. States would also have the option of granting or refusing permission to groups interested in removing their debris objects, which falls in line with this author's requirement for responsible sovereignty. A fee assessed by an appropriate body responsible for launches or another funding mechanism would have to be included, but the voluntary nature of participation and the right of states to approve removal of their space objects matches well with the principles of soft governance.

Lastly, a bounty system is very capable of delivering incremental results because it would have to focus on larger debris objects whose removal is more urgent in the eyes of participating states in its early stages. Upon demonstrating success at removing these objects, the system could be expanded to include larger portions of the orbital environment and more actors. Another important note is that a bounty system could be set up by a single major spacefaring nation to incentivize domestic companies to remove debris objects registered to that nation's government. Success at a national level like this could encourage other nations to establish their own systems, or lead to the creation of an international bounty system. This analysis demonstrates that bounty systems represent a promising policy option to pursue at both the national and international levels of governance.

d. <u>EDDEs</u>

Electro Dynamic Debris Eliminators represent the technical solution chosen for the demonstration of this author's criteria. As Table 4 depicts, some of the criteria are not applicable to EDDEs or other technical solutions. For example, embracing polycentrism is something that is entirely dependent on the policy choice that coincides with the implementation of a technical solution. The same is true for soft governance. EDDEs themselves also do not offer any solutions for fostering awareness and communication, although other technical solutions, such as improved SSA systems, may satisfy this requirement. EDDEs are compatible with responsible sovereignty due to the fact that they could be developed and deployed by a variety of states and other actors. However, this compatibility depends on the level to which they are adopted by various space actors. EDDEs are also capable of producing incremental results since they would have to be demonstrated on the largest and most pressing debris objects before moving on to smaller objects.

This analysis demonstrates that the viability of any technical solution is largely dependent on the policy choices that shape its implementation. Likewise, the way in which they are implemented can shape the policies governing their use and public perceptions of the technology and the orbital debris problem. This fact reinforces the point made earlier about the social construction of science and technology based on stakeholder interactions and concerns.

To further illustrate this point, this author can imagine two possible scenarios for the implementation of EDDEs. In the first, EDDEs are developed independently by a single nation, either privately or by its government. They are then used to remove a few of the nation's debris objects. A successful demonstration like this would be welcomed by many, but it may also be viewed with suspicion and fear by rival nations due to the dual-use potential EDDEs possess, both as peaceful debris eliminators and offensive weapons. Whether such a demonstration is viewed with approval or suspicion will depend on how open the demonstrating nation is about its intentions and how well it shares data about its development and use of EDDEs.

In the second scenario, EDDEs are developed jointly by an international consortium of nations, perhaps the ISS partners as suggested by Anzaldua & Dunlop (2014). The partners share the information and financial burden of development and implementation, and they cooperate on policy issues regarding which debris objects to target. This leads to international adoption of

EDDEs and real, incremental progress toward debris removal. These two scenarios are not exhaustive, but they demonstrate the relationships that social perceptions and policy have to technology and the importance of taking these relationships into account when addressing technical problems like space debris.

e. SDA and Data Sharing Organizations

Data sharing organizations like the Space Data Association (SDA) are an interesting mix of both policy and technical solutions. They must be set up by policy, but the data they share inherently depends on the application of relevant SSA technologies like radars and optical tracking equipment. Such organizations are inherently characterized by a multi-stakeholder structure because they include input from multiple actors, and they are likely to be polycentric as well. They also inherently meet the criterion for awareness and communication given that their primary purpose is to share data among their members and they meet the criterion for responsible sovereignty because it is up to member states and other actors to decide what data they will share.

As trust grows and the effectiveness of the organization becomes apparent, it is possible that the actors involved may feel more comfortable about sharing additional SSA information. Combined with other technical solutions that may be adopted (such as EDDEs), this provides data sharing organizations with a great deal of potential in terms of producing incremental results. Finally, given that their purpose is to voluntarily share information among like-minded members with an eye toward building trust and establishing norms of behavior, data sharing organizations like the SDA meet the criterion for soft governance.

This analysis shows that data sharing organizations are also a promising solution to the orbital debris problem. Additionally, they are capable of being adopted at various levels of governance and within or between various stakeholder groups. Data sharing organizations also have the extra benefit of meeting the criterion for awareness and communication by default, which can help facilitate other policy and technical solutions. As such, they may well be a good option for policymakers to focus on in the present since their success may help illuminate which additional solutions would be best for future progress.

X. Conclusions and Next Steps

In this article, this author surveyed the history and current state of space governance as it relates to the orbital debris problem, and framed the latter as a CPR issue. Additionally, Elinor Ostrom's framework for governing the commons and managing CPR issues at local levels was reviewed, along with more recent attempts to adapt her framework to global-level commons and emerging technological issues. Specifically, an examination of the attempts at governing the Antarctic, the oceans, the atmosphere, and the Internet received attention. From this, this author developed criteria for sustainability in the orbital environment based on Ostrom's principles and attempted to modify them in order to evaluate proposed solutions to the orbital debris problem. In so doing, this author also recognized the importance of the social construction of technology and identified stakeholder groups in the orbital environment not by their capabilities as had been done previously, but by their framings of space technologies and the orbital debris problem.

The five criteria developed in this article are not intended to promote one solution or a specific set of solutions to the orbital debris problem over others. Rather, they are intended to help scholars and policymakers evaluate proposed solutions as shown in the previous section and to stimulate discussion about ways forward. One conclusion that can be drawn from them, however, is that there is no single policy or technical solution that will solve the orbital debris problem on its own. Much like spacecraft and space operations rely on a system of systems in order to function, addressing orbital debris and enhancing space governance to cope with increased use in the twenty-first century will require a system of solutions. Policymakers should be aware of this and seek solutions that are adaptable, compatible with other solutions, and scalable to different levels of governance.

While this article is not intended to promote a single solution over any other, another conclusion that can be drawn from the research is the importance of increasing SSA capabilities and data sharing across the spectrum of stakeholders. There are likely several ways this could be accomplished and pursuing them will be an integral component to developing a system of solutions for the space debris problem. Stakeholders need to know as accurately as possible what objects are in orbit and how they behave both for safety in the present and for future planning. Should a catastrophic event, such as a major exchange of ASAT strikes, ever occur and result in a rapid degradation of the orbital environment, robust SSA capabilities will be critical in assessing the damage and determining how best to recover from it. SSA will not solve the problem alone, but it is an area that benefits all stakeholders and is perhaps a good place to start collaborating.

A third conclusion that this author's criteria reveal is that more traditional approaches to global governance, such as a binding treaty, are likely to face difficulty in negotiation and adoption. Further, they may be too narrow in scope to fully address the debris problem, or may not adequately address the concerns of key stakeholders, such as those concerned with social justice or national security, potentially leading to noncompliance or outright resistance. Formal treaty approaches in other global commons that were surveyed demonstrated these shortcomings, as does the PPWT promoted by some to address space sustainability. It is possible the PPWT could be modified to better comply with this author's criteria, but it may be rendered moot if more flexible solutions like the Code of Conduct achieve adoption in the near future.

Finally, this author can conclude that more research is needed to refine these criteria and evaluate proposed solutions. This article surveyed approaches used in other global commons, but it is probable that more in-depth reviews of each of these in future studies could reveal further lessons that could refine these new criteria for sustainability. Likewise, more in-depth looks at specific policy and technical solutions using these new criteria could further demonstrate their utility and highlight areas where improvement is needed. Additional studies that take a closer look at different stakeholder groups, particularly emerging space powers and developing countries, would also be helpful in testing and modifying these criteria. This article attempted to survey each stakeholder group, but the literature on some of them is scant and it is therefore difficult to infer their interests without making assumptions that could be too broad. Given the social construction of science and technology as acknowledged in this article, it would be particularly helpful if scholars and policymakers from emerging stakeholder groups in the space environment contributed to future studies, as they would be able to speak from direct experience about their interests and goals. Finally, further studies on the design of new institutions or modifications to existing ones that can facilitate collaboration between stakeholders as illustrated in this author's adaptation of the governance triangle would be helpful in advancing proposed policy solutions.

In summary, this article synthesizes a wealth of information from a variety of ongoing conversations relating to CPR issues and establishes a framework for moving the process of addressing orbital debris and space governance forward. More work is needed to refine this framework and implement solutions. Given the rising global interest in space activities and the increased use of space expected in the coming years, it is imperative that this work be carried out soon in order to preserve the sustainability of the orbital environment.

References

Abbott, K. W. (2011). The transnational regime complex for climate change. *Environment & Planning C: Government & Policy, Forthcoming*.

Abbott, K. W., & Snidal, D. (2004). Pathways to international cooperation.

Abbott, K. W., & Snidal, D. (2009). The governance triangle: regulatory standards institutions and the shadow of the state.

Abbott, K. W., & Snidal, D. (2010). International regulation without international government: improving IO performance through orchestration. *The Review of International Organizations*, *5*(3), 315-344

Adilov, N., Alexander, P. J., & Cunningham, B. M. (2013). Earth Orbit Debris: An Economic Model. *Available at: SSRN 2264915*.

Anzaldua, A., & Dunlop, D. (2014). Meeting the Threat of Orbital Debris. *To the Stars International Quarterly, (10)*. 128-150. Retrieved from: http://www.nss.org/tothestars/ToTeStars_010_ 2015jan.pdf.

Agrawala, S., Broad, K., & Guston, D. H. (2001). Integrating climate forecasts and societal decision making: challenges to an emergent boundary organization. *Science, Technology & Human Values*, *26*(4), 454-477.

Barrett, S. (1998). Political economy of the Kyoto Protocol. *Oxford review of economic policy*, *14*(4), 20-39.

Benedick, R (1998). *Ozone Diplomacy: New Directions in Safeguarding the Planet*. Cambridge, MA: Harvard University Press.

Bensoussan, D. (2010). Space tourism risks: A space insurance perspective. *Acta Astronautica*, *66*(11), 1633-1638.

Betsill, M. M., & Bulkeley, H. (2004). Transnational networks and global environmental governance: The cities for climate protection program. *International Studies Quarterly*, *48*(2), 471-493.

Blay, S. K. N., & Tsamenyi, B. M. (1990). Australia and the Convention for the Regulation of Antarctic Mineral Resource Activities (CRAMRA). *Polar Record*, *26*(158), 195-202.

Burns, C. (2013, November 15). Space junk apocalypse: just like *Gravity*? *The Guardian*. Retrieved from: http://www.theguardian.com/science/blog/2013/nov/15/space-junk-apocalypse-gravity.

Burzykowska, A. (2009). Smaller states and the new balance of power in space. *Space Policy*, *25*(3), 187-192.

Chow, T., & Weeden, B. C. (2013) Engaging All Stakeholders in Space Sustainability Governance Initiatives. *Secure World Foundation.*

Clark, S. (2015). Power system failure likely cause of military satellite explosion. *Spaceflight Now*. Retrieved from: http://spaceflightnow.com/2015/03/04/power-system-failure-likely-cause-of-military-satellite-explosion/.

Crowther, R. (2011). The regulatory challenges of ensuring commercial human spaceflight safety. *Space Policy*, *27*(2), 74-76.

David, L. (2013). Russian Satellite Hit by Debris from Chinese Anti-Satellite Test. *Space.com.* Retrieved from: http://www.space.com/20138-russian-satellite-chinese-space-junk.html.

DeFrieze, D. (2014). Defining and Regulating the Weaponization of Space. *National Defense University*. Retrieved from: http://ndupress.ndu.edu/Portals/68/Documents/jfq/jfq-74/jfq-74_110-115_DeFrieze.pdf.

Ehrenfreund, P., Race, M., & Labdon, D. (2013). Responsible space exploration and use: Balancing stakeholder interests. *New Space*, *1*(2), 60-72.

European Union. (2014). DRAFT International Code of Conduct for Outer Space Activities. Retrieved from: http://www.eeas.europa.eu/non-proliferation-and-disarmament/pdf/space_code_conduct_draft_vers_31-march-2014_en.pdf.

Flournoy, M., & Brimley, S. (2009, July). The contested commons. In *US Naval Institute Proceedings* (Vol. 135, No. 7, pp. 1-277).

Griggs, M. (2016). Tiny Debris Chipped a Window on the Space Station. *Popular Science*. Retrieved from: http://www.popsci.com/paint-chip-likely-caused-window-damage-on-space-station.

Guardian. (2011). Canada pulls out of Kyoto protocol. *Guardian*. Retrieved from: http://www.theguardian.com/environment/2011/dec/13/canada-pulls-out-kyoto-protocol.

Guston, D. H. (2001). Boundary organizations in environmental policy and science: an introduction. *Science, technology, and human values*, 399-408.

Hardin, G. (1968). The tragedy of the commons. *Science*, *162*(3859), 1243-1248.

Hanson, W. (2014). Pricing Space Debris. *New Space*, *2*(3), 143-144.

Hertzfeld, H. (2011). Testimony for Hearing on the Office of Commercial Space Transportation's Fiscal Year 2012 Budget Request. *United States House of Representatives.* http://science.house.gov/sites/republicans.science.house.gov/files/documents/hearings/050511_Hertzfeld.pdf.

Hildreth, S. A., & Arnold, A. (2014). Threats to US National Security Interests in Space: Orbital Debris Mitigation and Removal. *Congressional Research Service.*

House. (2009). Keeping the Space Environment Safe for Civil and Commercial Users: Hearing Before the Subcommittee on Space and Aeronautics. *Committee on Science and Technology, United States House of Representatives*. Serial No. 111-22.

Hussain, M. M., & Howard, P. N. (2013). What best explains successful protest cascades? ICTs and the fuzzy causes of the Arab Spring. *International Studies Review*, *15*(1), 48-66.

International Maritime Organization. (2015). Overview. *United Nations.* Retrieved from: https://business.un.org/en/entities/13.

Ivanova, M. (2010). UNEP in global environmental governance: design, leadership, location. *Global Environmental Politics*, *10*(1), 30-59.

Kaplan, M. H. (2009). Survey of space debris reduction methods. In *Proceedings of AIAA SPACE 2009 conference & exposition* (pp. 14-17).

Kleinwachter, W. (2004). Beyond ICANN Vs ITU? How WSIS tries to enter the new territory of Internet governance. *Gazette*, *66*(3-4), 233-251.

Kessler, D. J., & Cour-Palais, B. G. (1978). Collision frequency of artificial satellites: The creation of a debris belt. *Journal of Geophysical Research: Space Physics (1978–2012)*, *83*(A6), 2637-2646.

Kessler, D. J., Johnson, N. L., Liou, J. C., & Matney, M. (2010). The Kessler Syndrome: implications to future space operations. *Advances in the Astronautical Sciences*, *137*(8), 2010.

ISECG. (2007). 2007 Annual Report. *International Space Exploration Coordination Group.* Retrieved from: http://www.globalspaceexploration.org/documents.

Johnson-Freese, J., & Weeden, B. (2012). Application of Ostrom's Principles for Sustainable Governance of Common-Pool Resources to Near-Earth Orbit. *Global Policy*, *3*(1), 72-81.

Johnson, N. L. (2012). Cleaning Up Space: The Development of International Space Debris Policies. *Harvard International Review*, *33*(4), 67.

Liability Convention. (1971). *United Nations Office for Outer Space Affairs.* United Nations. Retrieved from: http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introliability-convention.html.

Listner, M., & Rajagopalan, R. (2014). The 2014 PPWT: a new draft with the same and different problems. *The Space Review*. Retrieved from: http://www.thespacereview.com/article/2575/1.

Loomis, I. (2015). Air Force turns a keen eye on space junk. *Science*, *347*(6218), 115-115.

Maxwell, J., and Briscoe, F. (1997). "There's Money in the Air: The CFC Ban and Dupont's Regulatory Strategy". *Business Strategy and the Environment* 6: 276-286.

Martin, D. (2015). The Battle Above. *CBS News*. Retrieved from: http://www.cbsnews.com/news/rare-look-at-space-command-satellite-defense-60-minutes/.

Masson-Zwaan, T., & Freeland, S. (2010). Between heaven and earth: The legal challenges of human space travel. *Acta Astronautica*, *66*(11), 1597-1607.

Matney, M. J. (2005). Uncertainty in Orbital Debris Measurements and Models. In *4th European Conference on Space Debris* (Vol. 587, p. 45).

McCormick, P. K. (2013). Space debris: Conjunction opportunities and opportunities for international cooperation. *Science and Public Policy*, *40*(6), 801-813.

Miller, T. R., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., & Loorbach, D. (2014). The future of sustainability science: a solutions-oriented research agenda. *Sustainability science*, *9*(2), 239-246.

Mineiro, Michael, C. (2009). Assessing the risks: tort liability and risk management in the event of a commercial human space flight vehicle accident. *Journal of Air Law and Commerce*, *74*(2), 371.

Moltz, J. (2014). *Crowded orbits: conflict and cooperation in space*. Columbia University Press.

Moon Agreement. (1979). *United Nations Office for Outer Space Affairs*. United Nations. Retrieved from: http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/intromoon-agreement.html.

NASA Authorization Act of 2010. *US Congress*. Retrieved from: http://www.nasa.gov/pdf/649377main_PL_111-267.pdf.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press.

Ostrom, E., Burger, J., Field, C. B., Norgaard, R. B., & Policansky, D. (1999). Revisiting the commons: local lessons, global challenges. *science*, *284*(5412), 278-282.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change*, *20*(4), 550-557.

Outer Space Treaty. (1967). *United Nations Office for Outer Space Affairs*. United Nations. Retrieved from: http://www.unoosa.org/oosa/en/SpaceLaw/treaties.html.

Parsons, E.A. (2003). *Protecting the Ozone Layer: Science and Strategy*. Oxford, UK: Oxford University Press.

Petroni, G., Venturini, K., Verbano, C., & Cantarello, S. (2009). Discovering the basic strategic orientation of big space agencies. *Space Policy*, *25*(1), 45-62.

Prasad, M. Y. S. (2005). Technical and legal issues surrounding space debris—India's position in the UN. *Space Policy*, *21*(4), 243-249.

Rathman, K. A. (1999). Outer space commercialization and its ethical challenges to international law and policy. *Technology in Society*, *21*(2), 135-166.

Rescue Agreement. (1968). *United Nations Office for Outer Space Affairs.* United Nations. Retrieved from: http://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introrescueagreement.html.

Sarewitz, D., Clapp, R., Crumbley, C., Kriebel, D., & Tickner, J. (2012). The sustainability solutions agenda. *NEW SOLUTIONS: A Journal of Environmental and Occupational Health Policy*, *22*(2), 139-151.

SDA. (2015). SDA Overview. *Space Data Association.* Retrieved from: http://www.space-data.org/sda/about/sda-overview/.

Shackelford, S. J. (2009). Tragedy of the Common Heritage of Mankind, The. *Stan. Envtl. LJ*, *28*, 109.

Shackelford, S. J. (2014). Governing the Final Frontier: A Polycentric Approach to Managing Space Weaponization and Debris. *American Business Law Journal*, *51*(2), 429-513.

SIA. (2014). State of the Satellite Industry Report. Retrieved from: http://www.sia.org/state-of-the-satellite-industry-report/.

Stern, P. C. (2011). Design principles for global commons: Natural resources and emerging technologies. *International Journal of the Commons*, *5*(2), 213-232.

Su, J. (2010). The 'Peaceful Purposes' Principle in Outer Space and the Russia-China PPWT Proposal. *Space Policy*, *26*, 81-90.

UN. (2006). Space solutions for the world's problems. *United Nations Office for Outer Space Affairs.* Retrieved from: http://www.unoosa.org/oosa/oosadoc/data/documents/2006/stspace/stspace33_0.html.

UN. (2007). Space Debris Mitigation Guidelines. *United Nations Office for Outer Space Affairs.* Retrieved from: http://www.iadc-online.org/References/Docu/Space_Debris_Mitigation_Guide-lines_COPUOS.pdf.

UNCLOS III. (1982). United Nations Convention on the Law of the Sea. Retrieved from: http://www.un.org/depts/los/convention_agreements/texts/unclos/closindx.htm.

UNFCCC. (2014). Kyoto Protocol. *United Nations Framework Convention on Climate Change*. Retrieved from: http://unfccc.int/kyoto_protocol/items/2830.php.

van Wyk, J. A. (2008). Overview of the implementation status of the five United Nations treaties on outer space in African countries. *African Skies*, *12*, 90.

Vogler, J. (2012). Global commons revisited. *Global Policy*, *3*(1), 61-71.

Waz, J., & Weiser, P. (2013). Internet governance: The role of multi-stakeholder organizations. *Journal of Telecommunications and High Technology Law*, *10*(2).

Weeden, B. C., & Chow, T. (2012). Taking a common-pool resources approach to space sustainability: A framework and potential policies. *Space Policy*, *28*(3), 166-172.

Williams, R., & Edge, D. (1996). The social shaping of technology. *Research policy*, *25*(6), 865-899.

Williamson, M. (2003). Space ethics and protection of the space environment. *Space Policy*, *19*(1), 47-52.

Williamson, R. A. (2012). Assuring the sustainability of space activities. *Space Policy*, *28*(3), 154-160.

Woellert, K., Ehrenfreund, P., Ricco, A. J., & Hertzfeld, H. (2011). Cubesats: Cost-effective science and technology platforms for emerging and developing nations. *Advances in Space Research*, *47*(4), 663-684.

List of Acronyms

ASAT:	**Anti-Satellite**
ATS:	**Antarctic Treaty System**
CD:	**Conference on Disarmament**
CHM:	**Common Heritage of Mankind**
CoC:	**Code of Conduct**
CFCs:	**Chlorofluorocarbons (need to define in article)**
COPUOS:	**Committee on the Peaceful Uses of Outer Space**
CPR:	**Common-Pool Resource**
CRAMRA:	**Convention on the Management of Antarctic Mineral Resource Activities**
CSF:	**Commercial Spaceflight Federation**
EDDEs:	**Electro Dynamic Debris Eliminators**
EEZs:	**Economic Exclusion Zones**
FAA:	**Federal Aviation Administration**
FCC:	**Federal Communications Commission**
GEO:	**Geosynchronous/Geostationary Orbit**
GOE:	**Group of Experts**
GPS:	**Global Positioning System**
HEEO:	**Highly Eccentric/Elliptical Orbit**
IADC:	**Inter-Agency Space Debris Coordination Committee**
IAEA:	**International Atomic Energy Agency**
IAF:	**International Astronautical Federation**

ICANN:	**Internet Corporation for Assigned Names and Numbers**
ISS:	**International Space Station**
ISECG:	**International Space Exploration Coordinating Group**
ITSO:	**International Telecommunications Satellite Organization**
ITU:	**International Telecommunications Union**
LEO:	**Low Earth Orbit**
MEO:	**Medium Earth Orbit**
MSH:	**Multi-Stakeholder**
NASA:	**National Aeronautics and Space Administration**
NSS:	**National Space Society**
NGO:	**Nongovernmental Organization**
NOAA:	**National Oceanic and Atmospheric Administration**
NSS:	**National Space Society**
OST:	**Outer Space Treaty**
PCA:	**Permanent Court of Arbitration**
PAROS:	**Prevention of an Arms Race in Outer Space**
PPWT:	**Treaty on Prevention of the Placement of Weapons in Outer Space and of the Threat or Use of Force Against Outer Space Objects**
SDA:	**Space Data Association**
SIA:	**Satellite Industry Association**
SSA:	**Space Situational Awareness**
SWF:	**Secure World Foundation**
TCBMs:	**Transparency and Confidence Building Measures**

UK:	**United Kingdom**
UN:	**United Nations**
UNCLOS III:	**Third United Nations Convention on the Law of the Sea**
UNEP:	**United Nations Environmental Program**
UNFCCC:	**United Nations Framework Convention on Climate Change**
UNOOSA:	**United Nations Office for Outer Space Affairs**

Digging Up the Cosmos: Is Asteroid Mining Economically Feasible?

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ABSTRACT - Asteroid mining has been proposed as a means of developing new supplies of raw materials for use on Earth and in space related endeavors. Several prominent business leaders including Larry Page and Sir Richard Branson view asteroid mining as a viable lucrative long-term business investment. Given the vast amount of capital required and the numerous risks of any space related venture, how economically viable is asteroid mining? The purpose of this article is to understand whether a compelling business case for asteroid mining exists and, if so, to determine the potential timeframe until an asteroid mining venture can become profitable. This author reviews and analyzes the current literature on the topic utilizing several types of sources including public filings of named asteroid mining ventures, articles from mainstream business publications, and academic works concerned with the development and evaluation of profitable business cases. In doing so, a key component of this study involves analyzing the business cases of several terrestrial mining operations in extreme environments and compares them to potential asteroid mining scenarios. The findings of the research indicate the business case for asteroid mining is potentially financially attractive though it contains several major exposures and risks that are difficult to quantify. This suggests asteroid mining may not be viably profitable for several decades. Several recommendations are offered to improve the business case in order to make it more worthwhile in a shorter timeframe.

I. Introduction

This exercise focuses on a single research question. Specifically, can a profitable business case for asteroid mining be developed and defended? Indeed, such a business must be profitable and sustainable to make it worth pursuing. This article attempts to define criteria for evaluating the soundness of a business case and applies the criteria to a set of publicly established published financial assumptions for asteroid mining to answer this research question. This article identifies high level gaps in the asteroid mining business case and presents high level recommendations to address identified gaps. Interestingly, whether it is profitable or not, several newly-formed corporations have begun the process of trying to make asteroid mining a reality.

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II. Literature Review

a. Historical Context

Although the establishment of mining colonies in space was described by science and science fiction authors such as Arthur C. Clarke, Isaac Asimov, and Larry Niven, and globally popularized through the Star Trek and Star Wars series, serious scientific discussions regarding the extraction of asteroidal resources did not commence until the late 1970s. O'Leary et al. (1979) outlined technical specifications for a manned mission to asteroid 1977HB. The proposed mission would rely on the Space Shuttle plus a mass driver to retrieve a 100-meter fragment of the asteroid and extract approximately 500 million metric tons of material during a three-year mission. The proposal offered high level detail regarding launch requirements, fuel estimates, trajectory, rendezvous, capture, material processing, and return scenarios. The cost estimate for this mission was estimated to cost $12-14 billion or about $24/kg of captured mass with an addendum, which suggests that capturing a much larger asteroid could result in a decrease in the cost/kg ratio down to $.50/kg (O'Leary et al., 1979).

For the next decade, these types of ideas were effectively tabled and it was not until 1992 when McKay, Duke, and McKay (1992) chaired a NASA-sponsored workgroup that the topic became viable. McKay et al. (1992) delivered an extensive report on potential exploitation of lunar and asteroidal resources. The report included an overview primer on terrestrial mining and the implications for extraterrestrial mining (Gertsch, 1992), the outline of an enhanced ground-based observation program to locate 400-500 previously unobserved near-Earth asteroids by 2012 (Gaffey, 1992), and an overview of a conceptual space mission model for asteroid mining (Lewis, 1992). Moreover, the report led to more academic debate and exploration of the topic. Kargel (1994) suggested the LL chondrites (stony) and metallic asteroids contained large quantities of precious minerals, which could represent a ten-fold increase over the global production rate. This work included an estimate of the market opportunity for precious metals from asteroids at approximately $900 Billion over 40 years (Kargel, 1994). Lewis (1997) advocated the capture and exploitation of a near-Earth asteroid (NEA) threatening an impact with the Earth. This would have a dual benefit of saving humanity from potential extinction while providing extensive supplies of metallic resources (Lewis, 1997). Kargel (1997) called for a systematic program of government incentives, and exploratory science, including deep space missions to support private industry as well as investors as they perform "the real work, take the greatest risks, and reap the biggest profits" of asteroid mining. As a prelude to asteroid mining, NASA's OSIRIS-Rex mission, launched in September of this year, will attempt to rendezvous with Asteroid Bennu and return the first directly retrieved asteroidal sample to the Earth in 2023 (Wibben & Furfaro, 2015).

b. Asteroid Targets and Materials

The Main Asteroid Belt, located between Mars and Jupiter, is the principal source of asteroids within the solar system. Asteroids are pristine records of the conditions that existed during the early formation of the solar system 4.5 Billion years ago (Chapman, 1999; Gaffey, Burbine, & Binzel, 1993). They are the descendants of planetesimals produced as the solar nebula collapsed and the terrestrial planets formed (Gaffey, 1997). Although the actual number of asteroids in the main belt is unknown, Tedesco et al. (2005) estimated approximately $1.9 * 10^6$ asteroids with a diameter greater than one kilometer exist in the Main Belt.

The size and shapes of asteroids are a direct result of the intricate and violent collisional processes occurring after they were formed (Marchis, 2006). Most asteroids are irregularly shaped as a result of numerous collisions making them far more difficult to land on than a spherically shaped body (Gaffey et al., 1993), as reflected by the odd shapes of asteroids 433 Eros and Itokawa, which represent the only two asteroids on which spacecraft have landed. Collisions may change the orbital path of an asteroid and direct it inward on a new orbit which may pass close to or cross the orbit of the Earth (Lewis, 2015), The first NEA was discovered in 1898 (Asteroid 433 Eros) and only approximately 500 had been found over the next hundred years (Phillips, 2013). After the impact of comet Shoemaker-Levy-9 into Jupiter in 1994 produced an Earth-sized hole in the planet's gas cloud, funding for NEA observations dramatically increased. This resulted in the discovery of over 10,000 NEAs by 2013 (Phillips, 2013). Of these, only about ten percent are larger than one kilometer and there are probably only a few dozen more of these large NEAs currently undiscovered (Phillips, 2013). Mainzer et al. (2014) estimate that a population of approximately 20,000 NEAs exists with diameters greater than 100 meters.

NEAs represent the near-term opportunity for asteroid mining because their location proximate to Earth's orbit makes NEAs easier and less expensive to reach than asteroids in the Main Belt (Lewicki, 2013; Lewis, 2015). Approximately half of the NEA population requires less fuel to get to than our Moon (Lewicki, 2013). Approximately 200 of these are greater than one kilometer in size (Lewis, 2015). Several researchers have developed models to estimate the asteroid resource map for near-Earth space (Sanchez & McInnes, 2011), the number of robotic probes (~ 24) needed to find a single ore-bearing asteroid (Elvis & Esty, 2014), and the number of ore-bearing NEAs (~ 10-30, conservatively) (Elvis, 2014). Target selection for mining operations will include analyses of the asteroid's gravity field, launch and return windows from Earth and the velocity (Δv) required to travel to the asteroid and back, and mineral composition (Boden, Hein, & Kawaguchi, 2015). Targets offering a combination of high potential mineral return and easiest accessibility from Earth will receive highest priority (Lewicki, 2013).

Asteroids are currently believed to contain infinitely larger supplies of specific minerals compared to what is found on Earth (Lewicki, 2013). There are three classifications of material targets on NEA's. The first group, volatiles and water, consists of hydrogen (H), carbon (C), nitrogen (N), and oxygen (O). The second group, platinum-group metals (PGM), is composed of ruthenium (Ru), rhodium (Rh), palladium (Pd), osmium (Os), iridium (Ir), and platinum (Pt). The third group, industrial metals, consists primarily of iron (Fe), cobalt (Co), and nickel (Ni) (Lewicki, 2013). Four types of asteroids represent prime mining targets for the aforementioned materials: carbonaceous asteroids (C, D, P, G, B or F-types); S-type or Q-type "stony" asteroids with mixtures of olivine, pyroxene, and metal; and M-type asteroids composed of pure metal (Gaffey, Bell, & Cruikshank, 1989; Lewis, 1992, 2015).

The volatiles and water found in asteroids will deliver in situ resources to mining companies through chemical transformation into potable water, radiation shielding, fuel, solvent, fertilizer, and refrigerant (Lewicki, 2013), based on Lewicki's and his team's experiences of landing the Mars Exploration Rover (MER) rovers and the Curiosity rover on Mars when they worked at the Jet Propulsion Laboratory (JPL). They feel they know how to do this and speak about it with confidence. These initial products will be used to supply subsequent waves of robotic missions dedicated to the detection, extraction, and retrieval of ore from asteroids (Lewicki, 2013). PGMs and industrial metals will be extracted primarily for terrestrial use and sold on the commodities market. Of the materials found on asteroids, PGMs have the most value on Earth primarily due to their scarcity (Crundwell, Moats, Ramachandran, Robinson, & Davenport, 2011; Diederen, 2009; Lewicki, 2013). PGMs are also valuable because they are easy to work with, have visual appeal, are highly conductive, are resistant to corrosion, have high melting points and catalyze chemical reactions (Crundwell et al., 2011).

A space voyage to a typical NEA asteroid mine will consist of several different distinct temporal phases. These include Earth launch to Low Earth Orbit (LEO), transfer from LEO to the NEA, arrival at the NEA, landing on the NEA, extended stay on the NEA engaged in mining operations, launch from the NEA surface, departure from the NEA, transfer to Earth orbit, re-entry into Earth atmosphere, and arrival at Earth (Boden et al., 2015; Korsmeyer, Landis, & Abell, 2008; Sharma & Mahajan, 2013; Zimmer & Messerschmid, 2011; Zimmerman, Wagner, & Wie, 2015). The transit phases to and from the asteroid (~ six months of total time) and the extended stay on the NEA for mining operations (~ six months to over a year of total time) will likely total upwards of at least eighteen months for the round trip (Sharma & Mahajan, 2013; Tardivel et al., 2015; Zimmer & Messerschmid, 2011).

Extracting and processing ore on an asteroid represent several daunting technical challenges compared to terrestrial operations. For example, on Earth mining PGMs requires separating PGM-rich ore from PGM-poor rock; isolating PGMs into a flotation concentrate; smelting the concentrate and converting in to a matte richer in PGMs than the starting concentrate; separating PGMs in the matte from base metals through magnetic concentration or leaching; and refining the resulting concentrate into PGMs with greater than a 99.9% purity level (Crundwell et al., 2011). These processes, perfected in Earth's gravity environment, are unsuitable for the reduced gravity associated with an asteroid and because the research in adapting these techniques to gravity-free processing techniques has remained stagnant (Lewis, 2015). Nevertheless, a host of new technologies including controlled foam injection, electric rock breaking, microwave drilling, electrostatic/magnetic field crossing, and magnetic separation are being evaluated for use in an asteroid mining environment (Ge & Satak, 2014; Lewis, 2015).

c. The Economics of Asteroid Mining

The success of any space-based investment depends on the likelihood of making a profit for the company and its shareholders. A venture such as asteroid mining represents a unique challenge. While the space mining companies that currently exist continue to work toward implementation of their vision, none of them have yet actually mined an asteroid. The numbers offered here are estimates based on the best comparisons available from terrestrial operations.

i. Investment Climate

Investors in spacefaring ventures in general, and asteroid mining in particular, involve wealthy individuals with a successful track record with new ventures and private equity firms (Mathurin & Peter, 2006). This is a close-knit community consisting of those who believe that space economics represents a potential huge wave of expansion that will turn current billionaires into trillionaires (Mathurin & Peter, 2006). The individual investors in Deep Space Industries (DSI) and Planetary Resources (PR) come from cutting-edge companies such as Google, Virgin Galactic, and Microsoft, other spacefaring ventures such at the X-Prize or Space Adventures, and proven successful industrial firms such as Bechtel Corporation (Belfiore, 2012; Mathurin & Peter, 2006; Nathan, 2012). They are willing to take extraordinary risks to make money and are currently taking a long-term view of their investments in asteroid mining (Belfiore, 2012).

Several researchers compared the climate surrounding asteroid mining to that of the early days of expansion into the western United States (Elvis, 2012a, 2012b; Kargel, 1997; Shaw, 2013; Slezak, 2013). The comparison is extended to include the need for government to play a role in enabling private investments for asteroid mining to flourish through technology transfer, financial incentives, or relaxed regulations (Genta, 2014; Marks, 2012; Reynolds, 2013; Shaw, 2013; Slezak, 2013). Elvis (2012a) suggests government should "buy down the risk" of initial investment in asteroid mining. Crandall (2012) goes further, calling for NASA to take the lead in developing asteroid mining technology and actually executing the first several prospecting missions.

At this initial stage of development in the industry, there are no actual profit and loss figures from asteroid mining firms that could be used to determine if the initial business plan was sound. Both PR and DSI are privately held and thus not required to file publicly available financial statements. Neither firm responded to repeated requests for an interview or materials to support this project. Nevertheless, there are several solid academic works that address the economic conditions specifically required to produce a business case for asteroid mining, including the variables, key relationships within a model, and open questions that remain unanswerable.

ii. Tools to Evaluate Asteroid Mining Investment

Gertsch and Gertsch (2005) developed an overview approach and tools for application to space mining ventures. In this model, government may play a role in launching initial ventures and allow private companies to make a profit wherever possible (Gertsch & Gerstch, 2005). During the initial stages of operation, asteroid mining firms will likely see little to no profit due to the lack of an existing market for space minerals. Mining operators must be prepared to stay the course early on while attempting to ensure that their products are saleable (Gertsch & Gerstch, 2005). Key drivers for costs include research and development (R & D); exploration and delineation; construction and infrastructure development; operations; engineering; environmental; sales, general, and administrative expense (S, G & A); and time value of money (TVM) (Gertsch & Gerstch, 2005). Returns are analyzed using the concepts of discounted cash flows (DCF), return on investment (ROI), and net present value (NPV) (Gertsch & Gerstch, 2005). Payback period is associated with risk and ROI. The higher the risk, the shorter the desired payback period and the higher the desired ROI (Gertsch & Gerstch, 2005).

Mark Sonter, a founding member of DSI, has written several critical papers regarding the formal structure of the quantitative asteroid mining business case including key technical drivers of cost that must be evaluated as trade-offs (Sonter, 1997, 2001). Sonter (1997) suggests in situ propellant is a key driver of the economics of mining asteroids because the velocity (ΔV) to return material to Earth is less than the delta V (ΔV) required to launch from Earth. High in situ propellant production can potentially allow for up to one hundred times the mass being returned to Earth as was launched (Sonter, 1997). In addition to propellant, propulsion system economics, project time duration, and the time value of money play key roles in determining profitability. Sonter (1997) outlines a robust quantitative model for calculating the net present value (NPV) of asteroid mining displayed in Equation 1 below:

$$NPV = C_{orbit}\ M_{mpe}\ f\ t\ r\ e^{-\Delta v/ve}\ (1 + i)^{-a3/2} - (C_{manuf}\ (M_{mpe} + M_{ps} + M_{ic}) + B\ n) \quad \textbf{(1)}$$

Where:

- C_{orbit} is the per kilogram Earth-to-orbit launch cost [$/kg];
- M_{mpe} is mass of mining and processing equipment [kg];
- f is the specific mass throughput ratio for the miner [kg mined / kg equipment / day];
- t is the mining period [days];
- r is the percentage recovery of the valuable material from the ore;
- Δv is the velocity increment needed for the return trajectory [km/s];
- ve is the propulsion system exhaust velocity [km/s];
- i is the market interest rate;
- a is semi-major axis of transfer orbit [AU];
- M_{ps} is mass of power supply [kg];
- M_{ic} is mass of instrumentation and control [kg];
- C_{manuf} is the specific cost of manufacture of the miner etc. [$/kg];
- B is the annual budget for the project [$/year]; and
- n is the number of years from launch to product delivery in LEO [years].

Ross (2001) developed a paper at Caltech reviewing the resources available from NEAs, as well as the technical engineering aspects of possible mining project designs, including a survey of mission plans, and mining and extraction techniques that may be used. In this paper, Ross (2001) amended Sonter's NPV equation to include the following summation in Equation 2 below that includes all the probabilities (j) over all possible scenarios (s) for the Expectation NPV (ENPV):

$$ENPV = \sum_{j=1}^{S} P_j NPV_j \quad \textbf{(2)}$$

Ge and Satak (2014) amended the NPV model created by Sonter (1997) to more accurately account for fuel used to reach the target asteroid. Also included in this work was a simpler view of the cost of mining (C_M) that is expressed as Equation 3 below:

$$C_M = C_{miner} + C_{s/c} \quad \textbf{(3)}$$

Where:

- C_{miner} = Cost of mining equipment; and
- $C_{s/c}$ = Cost of spacecraft

The cost of the miner in this example is linearly dependent on the mass of the miner while the cost of the spacecraft is dependent on the mass off the miner and the fraction of the total spacecraft mass representing the payload (Ge & Satak, 2014).

Andrews et al. (2015) developed an architecture for commercial asteroid mining including an industrialization architecture, transportation elements, research and development (R&D), and construction and exploration. NPV analysis using financial assumptions was actually run through the model and generated positive results. The model indicated over a 20-year period, terrestrial PGM supply could be increased by fifty percent including the added benefits of 1,500 tons of propellant available annually in low Earth orbit and low cost solar panels available at geosynchronous Earth orbit (GEO) (Andrews et al., 2015). The investment would pay back a discounted NPV/ROI of approximately twenty-two percent (Andrews et al., 2015). An aggressive case using assumptions for increased equipment and construction activity in space generated an NPV/ROI of forty-two percent with a net cash from of $19 billion annually from fifty-five mines (Andrews et al., 2015). Amador et al. (2014) provide guiding principles for work breakdown structures and costing relationships for a NASA/JPL Flagship class mission.

iii. Defining an Effective Business Case

In order to properly evaluate the effectiveness of the business case, it is critical to understand the basic elements involved and the different applications that may apply to asteroid mining. McCready (2005) offers a basic primer outlining key terms within a business case, how these are used, and their relationships. They include the total Cost of Ownership (TCO), Return on Investment (ROI), Net Present Value (NPV), Internal Rate of Return (IRR), and Equity Value Analysis (EVA) (McCready, 2005). Salzmann et al. (2005) present a review of business case research including a discussion of theoretical frameworks, instrumental studies analyzing corporate social or environmental performance against financial performance, descriptive studies examining managerial perceptions and practices, and finally tools for coaching or valuation. Rogoff (2015) suggests nine elements of a credible business case that include a stated goal of financial return (consisting of NPV, payback period, and IRR), amount of upfront investment, revenue generation strategy, payment of variable costs, payback of initial investment, marketplace positioning, competition, legal framework, and risk or questionable areas.

Wheeler and Sillanpää (1998) advocate a “stakeholder first” view during the construction of the business case. Customers, employees, investors, and external stakeholders all need to have quality input during the preparation or revision of a business case. Failure to do this may result in a decrease in competitiveness and increased risk (Wheeler & Sillanpää, 1998). Porter (2008) provides a generic strategic framework for businesses based on competitive economic forces. The forces are rivalry among competitors, supplier power, buyer power, threat of new entrants, and threat of substitute products (Porter, 2008). Understanding these forces allows companies to strategically position themselves in the marketplace and develop strategies necessary to achieving the goals of their business case. Henisz and Gray (2012) developed a case study for examining the Newmont Mining Company’s Ahafo gold mine in Ghana. This work provides a comprehensive business case for a precious metals mining operation in a terrestrial location that can be applied as an analog to the examination of a theoretical asteroid mining business case.

III. Research Methodology

The methodology utilized here consists primarily of review and critical analysis of peer-reviewed journal articles on the asteroid mining and the process of developing a business case.

Papers concerned with the technical process, environmental concerns, business model, organization, and investment philosophy of asteroid mining are analyzed. Publications from recognized groups or industry watchers such as NASA, Bloomberg, The Wall Street Journal, Space News, and Space Today Online are considered as well. This article also assesses academic sources concerned with the development of viable business models in order to determine an effective model for specifically evaluating the asteroid mining business case. Terrestrial mining operations in extreme environments are investigated to understand the applicability as an analog to mining in deep space. Public statements and publications of two asteroid mining companies, DSI and PR, are evaluated. Microsoft Excel is utilized to run a standard NPV calculation. Finally, selected public statements and interviews with key figures in the asteroid mining industry including Peter Diamandis, Larry Page, David Gump, and others are studied to add background context to the research.

IV. Analysis and Discussion

There are several factors that require consideration as the business case for asteroid mining is constructed and evaluated. The revenue opportunity is the initial "hook" used to attract investors. Identification and quantification of the major and minor components of the revenue opportunity are necessary as a means of providing initial credibility to the business case. Fundamental assumptions regarding costs, as known, must be estimated and categorized. Risks need to be initially identified and categorized. Finally, the business case must present an acceptable return to investors over a reasonable period or they will find another project in which to invest.

a. Revenue Opportunity of Asteroid Mining

The quest for riches is the likely primary motivation of investors in asteroid mining ventures. An analysis of the business case for an asteroid mining venture, beginning with examination of the revenue opportunity, will reveal in detail the prize investors are pursuing. This begins with a high-level understanding of the compositional makeup of desirable asteroids. Concentrations of valuable metallic materials can range widely on a given asteroid from zero to, in the case of cobalt, 64,000 parts per million (ppm) and greater (Lewis, 2015; Ross, 2001; Stewart, 2015). Table 1 details the average compositional makeup of desirable minerals from asteroids along with current market prices per kilogram (Lewis, 2015; Ross, 2001; Stewart, 2015). An estimate of the total amount of materials in NEAs is provided in Table 2 (Lewis, 2015; Ross, 2001).

Abundances of these materials are potentially staggering. Planetary Resources (PR), one of two of the major firms discussed here that are engaged in developing an asteroid mining capability, provides a simple estimate of the market opportunity from extracted NEA materials as > $1 trillion (Lewicki, 2013). Deep Space Industries (DSI), the other potential asteroid mining company, estimates NEAs contain enough material to support a population equivalent to one million times the current population of Earth (Lewis, 2015). DSI forecasts the total amount of resources in NEAs includes $11 trillion of iron (Fe), $70 trillion of Nickel (Ni), $70 trillion of cobalt (C), and $70 trillion of PGMs (Lewis, 2015). Genta (2014) suggests a single 30-meter asteroid may contain between $25-50 billion in platinum and a one-kilometer metal asteroid could contain two billion metric tons of iron-nickel ore, nearly three times the 2004 level of terrestrial production.

Table 1: Minor and Trace Elements in Asteroidal Metals[1]

Material	Low Silicon Concentration (ppm)	High Silicon Concentration (ppm)	Market Price ($/kg)
Platinum (Pt)	0.07	39	49,000
Palladium (Pd)	1.6	50	24,100
Osmium (Os)	0.03	41	12,900
Iridium (Ir)	0.4	40	25,700
Rhodium (Rh)	0.1	17	36,200
Ruthenium (Ru)	0.08	40	2,400
Phosphorous (P)	1,300	1,300	300
Silicon (Si)	0	25,0000	1.4
Gold (Au)	0.5	0.5	38,000
Cobalt (Co)	5,000	64,000	27.5

Table 2: Estimated NEA Asteroidal Resources[2]

Commodity	Mass (kg)
Silicates	7.50E+16
Ferrous Metals	1.00E+16
Fe in Oxides	1.00E+16
Water	5.00E+15
Carbon	3.00E+15
Nitrogen	3.00E+14
Sulfur	1.80E+15
Sulfides	4.50E+15

Armed with this information, it is possible to begin to assess the probable value of a typical asteroid. A one-kilometer spherical metallic asteroid is used here for modeling purposes. Several researchers including Kargel (1997) and Ross (2001) have suggested an asteroid of this type and size could yield one million tons of ore annually for 500 years. An important assumption is that there is uniform material distribution across a surface of uniform density. Using a model built in

[1] Adapted from Lewis, 2015, Ross 2001, and Stewart, 2015.
[2] Adapted from Lewis, 2015 and Ross, 2001.

Microsoft Excel (Appendix A), the hypothetical asteroid is capable of producing PGMs, plus gold, silver, cobalt, and semiconductor metal ore between $24.2 billion (if high silicon (Si) concentrations exist) and $68.2 billion (if low Si concentrations exist) on an annual basis at current market prices. One can then multiply the annual production of one million tons by 500 years of yield to derive a valuation of the metal ore of between $12.1 and $34.1 trillion dollars. This estimate is reasonable when compared to the estimate provided by the Asterank website (http://www.asterank.com/), owned by PR, which lists the value of the top ten most valuable NEAs (Table 3) as > $ 33.5 trillion (Webster, 2015). For comparative purposes, the estimated economic value of NEAs is dwarfed by that of their Main Belt counterparts that reside between the orbits of Mars and Jupiter, which consist of more than five hundred asteroids having estimated values greater than $100 trillion (Webster, 2015).

Table 3: Top 10 Most Valuable NEAs[3]

Asteroid	Semi Major Axis (AU)	Estimated Value ($T)
Phaethon	0.89	>$100
Gressmann	0.193	>$100
Tapio	0.246	>$100
Heracles	0.772	>$100
Sigurd	0.375	$46.80
1999 JM8	0.646	$45.00
1994 AH2	0.707	$43.78
Atlantis	0.336	$42.41
Poseidon	0.68	$38.13
Seleucus	0.456	$33.52

The financial valuation of the end products of a hypothetical chondritic asteroid is a little less straightforward than the metallic asteroid case. Lewis (1996) argues processing of a chondritic asteroid would yield approximately 40% water, approximately 3% water leachate, approximately 18% metals, and roughly 42% tailings, the latter of which are the waste product of mining. The tailings may have use as building materials and the water leachate is waste and thus has no economic value. Using a one-kilometer hypothetical chondritic asteroid of uniform density and spherical shape and a processing rate of one million tons of material annually as the model, we can derive material distribution from Lewis's estimate above and use current market prices to approximate the value of the end-products. The results are shown in Tables 4 and 5.

[3] Adapted from Webster, 2015.

Table 4: Material Yields of a One Kilometer Chondritic Asteroid[4]

Processed Mass/Yr. (kg)	Extracted Water (kg)	Water Leachate	Iron (Fe)	Nickel (Ni)	Cobalt (Co)	Total Metals (kg)
9.07E+08	3.63E+08	2.72E+07	1.50E+08	1.14E+07	1.63E+06	1.63E+08

Table 5: Estimated Revenue Opportunity from a One Kilometer Chondritic Asteroid[5]

Material	Market Price ($/kg)	% Sold to Earth	Est. Sales/Yr. ($M)	Est. Total Opportunity ($B)	Full Est. Opportunity/ per Yr. ($B)	Full Est. Total Opportunity ($T)
Iron (Fe)	$0.2	0%	$30	$15	$1,306.25	$653.10
Nickel (Ni)	$19	100%	$217.20	$108.60	-	-
Cobalt (Co)	$27.50	100%	$44.90	$22.50	-	-
Water (H_2O)	$9999.25	0%	$0	$0	$943.40	$471.70
-	-	**TOTAL**	$292.10	$146.10	-	-

Chondritic asteroids also yield estimates of staggering amounts of potential revenue opportunity from processed material, albeit significantly less than their metallic counterparts. In this case, the asteroid mining company would have a considerable amount of nickel and cobalt that it could conceivably sell on the terrestrial market (approximately $292M annually). Over the five-hundred-year processing horizon of the asteroid, the value of these materials is estimated at roughly $146 billion. Water ($H_2O$) and iron are different scenarios altogether. The mining company can store H_2O for later human consumption or, in a more realistic short-term scenario, convert H_2O into propellant used for returning supplies to Earth or expanding mining operations to another target asteroid. The propellant may also be sold in a space economic market to another spacefaring business or to a government. Iron would be used to construct long term facilities, ships, or human habitats needed by the mining company to extend operations. It might also be sold on the open new space market with a relatively low quantity sold to Earth for research or collectors.

Valuing the size of the revenue opportunity for H_2O and Fe is relatively simple when limited to the material cost only. The mining company needs only to be able to extract the material at a cost per mass that is less than the cost per mass of launch to LEO from Earth of the same material to make a profit. In this case, assuming a profit margin of fifteen percent, H_2O would need to be

4 Adapted from (Lewis, 1996).

5 Water price based on $1,200/Gal Launch to LEO cost ($10,000/kg). Iron and water opportunity valuation based on recovery of material at a cost < $10,000/kg cost of LEO launch and 15% profit margin. Adapted from Lewis, 1996, 2015, Ross, 2001, and Stewart, 2015).

extracted from the asteroid as a cost less than $1,043/gallon and Fe extracted at a cost of less than $8,695/kilogram for those materials to be profitable for the company to process. The estimated full year revenue opportunity and total opportunity for Fe and H_2O in Table 5 represent the *maximum* value of those materials on the space market. As long as H_2O and/or Fe can be easily procured in space for a price less than the price of launch of the same material from Earth, a viable market for these materials will exist at some established price representative of the value of those materials to the client. The key open questions concern the true costs of material extraction for the mining company and how long will it take for enough spacefaring companies to exist before a viable economic market can exist. It will be difficult to further constrain the revenue opportunity from asteroidal materials until these questions can be answered.

A practical look at the revenue side of asteroid mining adds a few sobering thoughts. Current Earth-based PGM production is 500 tons annually (Crundwell et al., 2011). This clearly suggests if miners could extract and process the vast supplies of PGMs on an asteroid, there is little chance that Earth could consume all of it, and thus the overall financial valuations of asteroidal PGMs are false. However, if an asteroid mine doubled Earth's PGM production and delivered 1,000 tons of PGMs annually plus other minerals such as gold, silver, or phosphorus, there is still a very attractive revenue opportunity both on short-term and long-term bases. There are likely new technological innovations that could be developed and introduced to the market if additional supplies of PGMs, perhaps at a cheaper price, were available. Excel modelling for this analysis provides estimates that the revenue from producing 1,000 tons of asteroidal PGMs plus other minerals could yield revenues from approximately $8.9 to $60.2 billion annually (see Appendix C).

The revenue model for asteroid mining is the single most attractive feature of the business case. The potential returns of this space-based business sector are large and can last a long time. If a company were able to achieve full production on this hypothetical one-kilometer metallic asteroid, it would be in the top 100 of Earth's largest corporations (Chen, 2014), and that is only based on one asteroid. It is understandable why wealthy and successful investors are gambling on this as yet nonexistent business.

b. Cost Assumptions and Estimates

Estimating a cost case for asteroid mining presents some difficulties. Understandably, neither PR nor DSI have published anything of substance on the topic of costs and the peer-reviewed literature is mostly focused on costs from a theoretical perspective. However, some basic assumptions can be inferred from the literature that will facilitate the construction of a cost model that will combine with the revenue projection to estimate the basic viability of the asteroid mining business case (Amador et al., 2014; Andrews et al., 2015). PR's published timelines serve as a guiding template for applying the cost and revenue assumptions for the model.

Several categories of costs are evaluated here including wages and benefits; facilities; launch; project management; spacecraft hardware and software; research and development; operations and maintenance; marketing and sales, insurance; and legal expenditures. The results are presented in Appendices D, E, and F. Staff salaries and benefits are assumed to be $200,000 per person for a thirty-person staff starting in the first year and growing at ten percent each year as estimated here based on a review of the documents and website publications of the two companies. Similarly, facilities are estimated based on listings for common multiuse commercial space and estimated at $850,000 lease cost annually. Several real estate expansions are added into the model over time to accommodate expansion. Launch costs are assumed to be a constant $10,000 per kilogram based on current listed NASA averages. Project management costs are estimated at one percent of the total hardware and software cost. Three classes of spacecraft are projected for use for the business case, PR Arkyd prospectors (11 kilograms mass, thirty million dollars total cost), mid-to-high capacity Class 1 processors (100,000-kilogram mass, one-billion-dollar cost), and ultra-high capacity Class 2 processors (100,000-kilogram mass, $1.5 billion cost).

These numbers are based on the author's estimates starting with the cost of high capacity terrestrial robotic mining equipment and extrapolating from there. No published estimate was found and the companies were not cooperative in this regard and so they are based on approximations of NASA Flagship mission type costs for each processor. The function of the Arkyd prospector is to locate potential targets, develop a detailed in-situ compositional analysis through remote sensing of the surface, and return samples to Earth for testing (Lewicki, 2013). Twenty-Five Arkyd prospectors are included in the business case analysis. To clarify for the purposes of this analysis, each piece of the robotic equipment required to perform all the mining tasks on the asteroid's surface is termed "processors." The processors contain all necessary equipment and technology infrastructure to mine, process, store, and return processed material. Two types of processors, Class 1 and Class 2, are assumed in the present model.

Research and development is assumed at a flat seventy-five million dollars spread across the project based on a standard level for this size of an enterprise. Operations and maintenance are valuated at a constant one percent of total cost in pre-mining years and fifteen percent when mining operations are underway. Insurance for launch and liability is estimated to be a constant one percent of total costs. Sales and marketing (one percent) and legal (one-half percent) are also constant cost assumptions. Estimated first year costs are assumed to be a total of $43.6 million, escalating to three billion dollars annually as full production is reached, a number that represents the sum of all the costs in the model.

Operational assumptions are made to provide guidance for the cost and revenue models. The analysis period is twenty-five years. The first four years focused on Arkyd prospecting missions to find a suitable mining target. The first Class 1 processor is deployed during the fifth year and a second in the seventh year. Class 2 processors begin arriving at the target in the ninth year with all deployed by the fourteenth year. The main items not included in the costing model include orbital trajectories, launch windows, and fuel requirements. These variables are specific to particular asteroid candidate targets identified for processing and would be useful when comparing the financial viability of mining one asteroid against another asteroid.

c. <u>Risk Factors for an Asteroid Mining Business Case</u>

Several types of risks exist that command attention. These include the operational risks of getting a robotic ship to an asteroid, landing, conducting mining operations, and returning cargo to Earth. There are risks in developing new technologies that may or may not work as intended in the space environment resulting in setbacks, rework, and prolonged timelines. Financial risks of various sorts threaten the bottom line, as cost overruns, investor apprehension, and failure to locate economically profitable ore can delay or even doom the entire project.

i. Technology Risk

Asteroid mining represents an amazingly lucrative opportunity for investors and company stakeholders. However, the path to riches contains significant challenges and multiple risks. Some of these risks have the potential to derail the business case entirely or diminish as well as elongate the monetary returns. The largest risk to the asteroid mining business case is uncertainty surrounding the ability to develop technology to successfully mine asteroids and return material to Earth. Although automated/robotic mining machinery and technology is deployed on Earth successfully in a variety of applications, mining in space has never been attempted. The automated technology required for asteroid mining is a “step-change” from the automated technology of terrestrial mining operations (Fisher & Schnittger, 2012). Step changes are R&D efforts to develop complex solutions in order to overcome significant technical challenges and therefore imply a significant departure from business-as-usual processes (Fisher & Schnittger, 2012). Such innovation takes place over long time horizons and requires a very substantial upfront investment with an uncertain outcome (Fisher & Schnittger, 2012). It is possible that technological challenges may arise, which cannot be overcome in the short term.

Orbiting the asteroid, landing on the surface, assembling and moving equipment on the surface, anchoring equipment to the surface, moving material into and through the processing site, dust, exposure to extreme temperatures, communications with Earth, maintenance operations, and repair operations are the major areas of technological challenge. Each of these is, in and of itself, represents a step change. Each will have to be addressed and perfected before full-scale mining operations can commence.

Development of a robotic mining infrastructure with the necessary hardening to operate in the deep space environment would seem to represent an example of an extreme step change when considering the overall process on an ongoing basis. Technological innovations of this type are deployed only after projects undergo multiple stages beginning with the initial idea; i.e., the ”proof of concept” or feasibility stage; and then moving on to the pilot project stage for an initial limited roll-out and initial test; the demonstration stage consisting of a trial run at a commercially significant scale; and the full-scale roll-out and commercialization of a technology where it becomes an integrated part of a wider process (Fisher & Schnittger, 2012). Unsuccessful technological innovations are discarded and replaced or modified at any point before moving on to the next phase of development, and typically very few succeed to full scale roll-out (Fisher & Schnittger, 2012). Step-change innovations rely on major technological advances and are considered high-risk due to the uncertainty of the technology and the amount of financial investment required to achieve success (Fisher & Schnittger, 2012). Failure of the asteroid mining business case is guaranteed unless appropriate technologies are developed and deployed in-house, as well as with collaborative partners. It is likely to require an international level of cooperation.

ii. Risk of Adverse Market Reaction to New Supplies of PGMs and Diminished Ore Quality

Reaction of the terrestrial PGM market represents multiple potential long term financial risks to an asteroid mining business case. A common argument exists suggesting that a large drop of PGM prices on the terrestrial market could have the effect of depressing various PGM prices below the point required by asteroid mining companies to make a profit (Endsor, 2014). While this argument seems credible, results obtained from the one-kilometer hypothetical metallic asteroid model presented here suggest otherwise. Adjusting terrestrial prices downward eighty percent for PGMs, fifty percent for semiconductor metals, and ten percent for gold and silver (see Appendix B) diminishes the annual total revenue opportunity from approximately $24.2 billion to $7.5 billion if high Si concentrations exist, or approximately $68.2 billion to $32.9 billion if low Si concentrations exist. Even with price reductions of ninety percent across the board, the mine will still be capable of annually producing between approximately $2.5 and $6.8 billion.

Diminished ore quality is probably a larger threat to an asteroid mining case than the threat of a market crash (Endsor, 2014). If asteroid mining companies are unable to produce materials at a quality comparable to terrestrial products, they may encounter significantly reduced demand for their products or, worse, they may find their ore unsaleable on the terrestrial market. An upside risk from the terrestrial market is the potential application of increased supplies of PGMs to new technologies. There are likely innovations in different stages of design of technologies that would be constrained without PGMs, but would be more practically feasible if a larger supply of PGMs was available at a reduced cost. An influx of asteroidal PGMs could satisfy this need and result in a wave of new technologies to benefit terrestrial consumers and industries.

iii. Risk of New Entrants, Property Rights, and Timing

A long-term risk to asteroid mining companies comes from late entrants to the business that enter after the technologies necessary for mining operations have been perfected and enhanced to increase efficiency. This could include making cheap in-space rocket propellant available to new companies desiring to mine Main Belt asteroids, thus allowing for vastly larger supplies of material to be available to the market than could be sourced from the NEA population composed mostly of smaller asteroids. Companies such as PR or DSI, first to the NEA opportunity, may find themselves squeezed out by others who get to the Main Belt first and extract more profitable resources. Practically, however, this scenario is probably unlikely unless a very robust space economy is developed as material supplies from NEAs become sufficient to supply Earth for many centuries.

Another key risk to an asteroid mining business case is the issue of property rights in space. The 1967 Outer Space Treaty forbids territorial claims beyond the Earth by all sovereign nations (Pop, 2000; Reynolds, 2013). Territorial claims are forbidden on the Moon and "other celestial bodies," but the definition of the term "celestial body" is the subject of an ongoing debate (Pop, 2000; Reynolds, 2013). Many will argue the treaty will prevent companies from even beginning mining operations while mining companies such as PR contend the treaty allows them the right to mine asteroids (Marks, 2012). Different solutions to the issue are being debated without a clear consensus about how to proceed. Options include the "Wild West" approach in which asteroid companies ignore the treaty and do what they want, accepting whatever consequences occur (Reynolds, 2013); treating recovered asteroid materials in a manner similar to the way fish are regarded under laws of the sea (Marks, 2012); and implementing national legislation to establish property rights for companies from that country to mine asteroids (Tronchetti, 2014). Rogoff (2015) believes the issue of legal authority over claims disputes or liability disputes between two spacefaring companies over damages suffered during space operations is a larger threat to an asteroid mining business case than the issue of property rights because companies currently have no sovereign court where disputes may be heard and resolved.

Timing represents another level of risk for the asteroid mining business case. Companies cannot establish mining operations on an asteroid and return massive profits in a short period of time. In a terrestrial mining operation, it can take years and sometimes decades for a mine in a remote location to reach full production. PR plans to return only small quantities from an asteroid within the next decade. For asteroid mining companies, this means establishing revenue streams from non-mining activities such as consulting services or systems integration. Both PR and DSI have active services businesses operating today, and in the case of PR, several small contracts with NASA and Department of Defense have been secured (Lewicki, 2013). If automated mining technology is not deployed on time, or if it is deployed and does not work as advertised, increased pressure will be placed on the services business to drive additional revenue. The company could be at risk of paying less attention to the core business of mining as they try to generate more short-term revenue. Delays in returning saleable ore from asteroids may also make an asteroid mining company less attractive to potential new sources of financing and may drive away long-time investors who want to cut their losses and get out of the asteroid mining game altogether.

iv. Constructing an NPV Model for a Hypothetical Asteroid Mining Business Case

Development of a model to project Net Present Value (NPV) for the present hypothetical case is fairly straightforward. NPV is defined as the sum of costs and revenues (often termed discounted future cash flow) over the lifetime of a project expressed in present day dollars. The investment period is assumed to be twenty-five years with a single up-front investment of $1.5B. The discount rate is assumed to be eight percent. All costs are taken from the aforementioned cost model. Revenue inputs are derived from assuming the production of up to 1,000 tons/annually of PGMs. Additionally, semiconductors, silver, and gold would be mined on our hypothetical one-kilometer metallic asteroid with full production occurring in year 15 after a ten-year ramp-up period. Present day market prices are assumed for mined commodities. A consulting and services business is assumed, initially generating $10M annually and growing to $247 million by year 25. An Excel spreadsheet is utilized to calculate results. The revenue inputs to the model are found in Appendices G, H, and I.

V. Results

The base case NPV of the initial $1.5 Billion investment over 25 years is $131.9 billion with a payback of 5.8 years. This suggests that the investment becomes profitable as soon as ore is returned to Earth. The analysis when re-run with discount rates of nine and ten percent yields very similar results. Variations in commodity pricing, calculation errors made during assessing prospecting data, lower than expected ore quality, lower yield rates, or an unexpected mineral mix are variables that can negatively impact the overall rate of success in mining exploration (Kreuzer & Etheridge, 2010). In order to simulate the risk and uncertainty associated with achieving exploration success, a variable termed, “exploration success rate” is added to drive a scenario where all costs remain the same while revenue from mining results were less than 100%. This provides a method to simulate and quantify, at some level, the negative value of stated risks. In Table 6, the exploration success rate is toggled between zero and one hundred percent with NPV and payback variables plotted for each value. The results in Table 6 suggest the mining operation is a good investment even with average mining results. One reason for this is the continued projected growth of the company's services business that provides and ongoing revenue stream. However, the encouraging NPV result of this hypothetical asteroid mining business case does not easily lead to a conclusion that billionaire investors will become trillionaires. For that to occur, an exponential increase in PGM demand or a rapid expansion in the space water/propellant business is required.

Table 6: NPV of Hypothetical One Kilometer Metallic Asteroid Mining Operation

Exploration Success Rate	NPV ($B)	Payback (Yrs.)
0%	($15.66)	13.09
1%	($15.66)	13.17
5%	($9.70)	13.18
10%	($2.24)	12.64
20%	$12.66	10.93
30%	$27.56	9.40
40%	$42.47	8.29
50%	$57.37	7.51
60%	$72.28	6.95
70%	$87.18	6.54
80%	$102.08	6.23
90%	$116.99	5.99
100%	$131.89	5.80

Table 7: NPV of Hypothetical One Kilometer Metallic Asteroid Mining Operation - 5 Year Delayed Production

Exploration Success Rate	NPV ($B)	Payback (Yrs.)
0%	($17.15)	13.09
1%	($16.16)	13.17
5%	($12.20)	13.25
10%	($7.26)	13.02
20%	$2.63	12.16
30%	$12.51	11.31
40%	$22.40	10.62
50%	$32.29	10.08
60%	$42.17	9.66
70%	$52.06	9.33
80%	$61.95	9.07
90%	$71.83	8.85
100%	$81.72	8.66

An additional NPV case uses the same inputs as the base case but assumes that full production from mining operations was delayed a full five years from year 15 to year 20. Design problems, production delays, or technology failures could constitute a delay of this type. The results shown in Table 7 project an NPV of $81.72 billion that is realized with an eight percent discount rate. As in the base case, this NPV model runs for the delayed production case utilizing higher discount rates obtained similar results. Application of the exploration success rate variable in the delayed production case suggests the investment is still a good one as long as the mining operations are not a complete and utter failure.

The major findings of this research together indicate that the business case for asteroid mining can close profitably yielding lucrative rewards for investors. This is primarily driven by the current high value of PGMs and their relative scarcity on the market, in addition to the massive abundances of PGMs and other materials available on asteroids. There are significant caveats to this result that deserve serious consideration. The lack of existing technology to mine robotically in space presents the largest obstacle to investors. There is no guarantee this technology can be developed or will operate successfully in the deep space environment. Investors must also consider the variable nature of terrestrial mining and add the complexity, harshness, and elongated timeframes of mining in the space environment prior to making an investment decision.

VI. Recommendations / Next Steps

This research was intended as a first step, "back-of-a-napkin" cut at the potential financial attractiveness of asteroid mining. It provides an important starting point for more detailed investigation that is required before moving forward. Future research needs to involve drilling down on all the basic points identified here as well as identifying gaps or omissions in this research, which, if addressed, could build on this foundation. Given the risks and technical intricacies of space exploration, as well as the unknowns of space mining, a lot of work remains to be done.

Construction and testing of the equipment, as best as possible on Earth and in low Earth orbit, will provide a proof of concept. This stage of the overall project is difficult, time consuming and risky, as new types of robotic machinery may perform differently in the terrestrial or in low Earth orbit than they do in deep space. Additional unforeseen costs may be incurred as deficiencies in technology or process are recognized and addressed. However, when successfully accomplished, the proof of concept will provide investors with confidence – and minimize the potential perceived risks – so they agree to move forward at each point in the overall construction phase as progress is demonstrated.

The key next step in the research is to select a target asteroid and make adjustments in the model to account for the asteroid size, orbital distance from Earth, fuel required, and the actual mineral yield from this asteroid. The ideal target is an NEA with an orbit that comes close to Earth. Timing of this mission would have to ensure as the processed material is ready for shipment when the asteroid positioned such that the return trip to Earth was as short as possible. This serves to reduce costs and provide early revenue returns, publicity of success, and drive future business.

The process of prospecting for the right asteroid is another factor that must be fully incorporated into the business case. In terrestrial mining, miners who dig for ore without extensive prospecting rarely strike the "mother lode". There are also cases of miners who come up dry even with extensive prospecting. The massive expense of an asteroid mining venture could be extremely unforgiving if the prospecting effort is conducted poorly or incompletely. It is critical for asteroid mining companies to succeed early on so as to retain the confidence of investors. Equally important is the need to retain adequate access to their purse strings.

Additional constraints on costs for the mining infrastructure also require attention. Moreover, revenue production requires development. A full assessment of the water and propellant production capabilities of an asteroid needs to be assembled and included in the financial analysis. Once these additional steps are accomplished, the NPV analysis including a Monte Carlo simulation can be developed to replicate, as closely as possible, a real scenario for asteroid mining and could perhaps be used to determine which individual asteroid(s) presents the best investment possibility.

VII. Summary and Conclusion

The old adage, "the rich get richer," is applicable to the business case for asteroid mining. The initial business case suggests there is serious money to be made and validates the presence of financial heavyweights in the investor lists of PRs and DSI. Based on the public records of their success, investors such as Page and Branson bet on far more winners than they do losers. Less wealthy investors have reason to be optimistic if they are only considering the potential revenue from asteroid materials. The elementary business case presented in this analysis suggests asteroid mining can be a lucrative, profitable business. This represents a significant change in clarity from risk assessment calculations of a decade ago.

Nevertheless, the risks and technology gaps associated with mining asteroids seem daunting and potentially insurmountable, presenting significant challenges to the business case. As noted with the recent activities of SpaceX and others, launch failures occur. When they do occur, catastrophic loss of the payload is the result, and while insurance payments can relieve the cost burden, loss of time as well as negative publicity may affect potential future efforts. Systems for landing on an asteroid and tethering equipment to it represents a complex set of technologies yet to be perfected. Communication failures, propulsion system failures, degradation of stabilization systems, computer glitches, and human error have all occurred during robotic missions on deep space missions, often resulting the loss of the spacecraft. All of these and other serious technical issues are possibilities during commercial robotic mining missions.

The business track records of the current investors in asteroid mining indicates that they are willing to accept these risks initially. As the development of robotic technology capable of mining an asteroid develops, it will be interesting to see how far investors are willing to go. Will they continue to support asteroid mining companies if they "strike out" the first several times or if they are unable to return product to Earth for a generation? Such assessments are difficult. For now, this is the business that these investors have chosen. One can conclude at this point that some bold moves are being made by those with vision and money who want to create dramatic change, forge a new space economy, and deliver new product to Earth that may improve our lives. One can remain hopeful that these dreamers' visions play out, but one also needs to view asteroid mining through the lens of a realist and understand there is a long course ahead with many roadblocks and setbacks that must be overcome before the pot of PGMs at the end of the "space rainbow" can be reached.

References

Amador, E., Lawson, M., Carrier, B., Parcheta, C., Albuja, A., Sheehan, J. P., Gainey, S. (2014). *Enceladus environmental explorer*. NASA/Caltech, Jet Propulsion Laboratory, Pasadena, CA.

Andrews, D. G., Bonner, K. D., Butterworth, A. W., Calvert, H. R., Dagang, B. R. H., Dimond, K. J., Yoo, C. J. (2015). Defining a successful commercial asteroid mining program. *Acta Astronautica, 108*(0), 106-118

Belfiore, M. (2012). How to mine an asteroid. *Popular Mechanics, 189*(8), 50.

Boden, R. C., Hein, A. M., & Kawaguchi, J. (2015). Target selection and mass estimation for manned NEO exploration using a baseline mission design. *Acta Astronautica, 111*(0), 198-221.

Chapman, C. (1999). *The new solar system: Asteroids* (4th ed.). Cambridge, UK: Cambridge University Press.

Chen, L. (2014). The world's largest companies: China takes over the top three spots. *Forbes*, May 7.

Crandall, W. B. C. (2012). Profitable asteroid mining: A pragmatic policy goal? *Space Wealth,* (July 20, 2012), 1-24.

Crundwell, F. K., Moats, M. S., Ramachandran, V., Robinson, T. G., & Davenport, W. G. (2011). Platinum-Group Metals, Production, Use, and Extraction Costs. In W. G. Davenport, F. K. Crundwell, M. S. Moats, V. Ramachandran, & T. G. Robinson (Eds.), *Extractive Metallurgy of Nickel, Cobalt and Platinum Group Metals* (pp. 395-409). Oxford: Elsevier.

Diederen, A. M. (2009). *Metals minerals scarcity and the elements of hope*. Paper presented at the Oil Drum/ASPO Conference, Alcatraz, Italy.

Elvis, M. (2012a). After Apollo: Creating an economically robust space policy by learning from the American west. *Harvard international Review, 33*(4).

Elvis, M. (2012b). Let's mine asteroids--for science and profit: the commercial dream of trawling space for valuable minerals could bring enormous benefits to a wide range of sciences. *Nature, 485*(7400), 549.

Elvis, M. (2014). How many ore-bearing asteroids? *Planetary and Space Science, 91*, 20-26.

Elvis, M., & Esty, T. (2014). How many assay probes to find one ore-bearing asteroid? *Acta Astronautica, 96*, 227-231.

Endsor, M. (2014). The economics of asteroid mining. *Economic News and Opinion,* (March 26, 2014).

Fisher, B. S., & Schnittger, S. (2012). *Autonomous and remote operation technologies in the mining industry: Benefits and costs*. Canberra, AU: BAEconomics Limited. Retrieved from: http://www.baeconomics.com.au/wp-content/uploads/2010/01/Mining-innovation-5Feb12.pdf.

Gaffey, M. J. (1992). Ground based observation of near Earth asteroids. In D. S. McKay, M. B. Duke, & M. F. McKay (Eds.), *Space Resources. Volume 3: Materials*. Houston, TX: National Aeronautics and Space Administration.

Gaffey, M. J. (1997). The early solar system. *Origins of Life and Evolution of the Biosphere, 27*(1-3), 185-203.

Gaffey, M. J., Bell, J. F., & Cruikshank, D. P. (1989). Reflectance spectroscopy and asteroid surface mineralogy. In R. P. Binzel, T. Gehrels, & M. Shapley (Eds.), *Asteroids II*. Tucson, AZ: University of Arizona Press.

Gaffey, M. J., Burbine, T. H., & Binzel, R. P. (1993). Asteroid spectroscopy: progress and perspectives. *Meteorites, 28*, 161 -187.

Ge, S., & Satak, N. (2014). *An improved economic model for asteroid mining*. Paper presented at the Houston Annual Technical Symposium, Houston, TX.

Genta, G. (2014). Private space exploration: A new way for starting a spacefaring society? *Acta Astronautica, 104*(2), 480-486.

Gertsch, R. E. (1992). To build a mine: Prospect to product. In D. S. McKay, M. B. Duke, & M. F. McKay (Eds.), *Space Resources. Volume 3: Materials*. Houston, TX: National Aeronautics and Space Administration.

Gertsch, R. E., & Gerstch, L. (2005). *Economic analysis tools for mineral projects in space*. Paper presented at the Space Resources Roundtable, Golden, CO.

Henisz, W. J., & Gray, T. (2012). Calculating the net present value of sustainability initiatives at Newmont's Ahafo Mine in Ghana. *The Wharton School of the University of Pennsylvania, 0*(0), 1-40.

Kargel, J. S. (1994). Metalliferous asteroids as potential sources of precious metals. *International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abstracts, 32*(5), 129-141.

Kargel, J. S. (1997). Digging for gold. *Astronomy, 25,* 48-52.

Korsmeyer, D. J., Landis, R. R., & Abell, P. A. (2008). Into the beyond: A crewed mission to a near-Earth object. *Acta Astronautica, 63*(1–4), 213-220.

Kreuzer, O. P., & Etheridge, M. A. (2010). Risk and uncertainty in mineral exploration: Implications for valuing mineral exploration properties. *AIG News, 100*(May 2010), 20-29.

Lewicki, C. (Producer). (2013, February 20, 2015). Planetary Resources and the mining of asteroids. Retrieved from: https://www.youtube.com/watch?v=AILO71zIsek.

Lewis, J. S. (1992). Asteroid Resources. In D. S. McKay, M. B. Duke, & M. F. McKay (Eds.), *Space Resources. Volume 3: Materials*. Houston, TX: National Aeronautics and Space Administration.

Lewis, J. S. (1996). *Mining the sky: The untold riches from the asteroids, comets, and planets*. New York, NY: Basic Books.

Lewis, J. S. (1997). Platinum apples of the asteroids. *Nature, 372*(6506), 499-500.

Lewis, J. S. (2015). *Asteroid Mining 101: Wealth for the New Space Economy*. Moffett Field, CA: Deep Space Industries.

Mainzer, A., Bauer, J., Grav, T., Masiero, J., Cutri, R. M., Wright, E., Masci, F. (2014). The Population of Tiny Near-Earth Objects Observed by NEOWISE. *The Astrophysical Journal, 784*(2), 110. Retrieved from http://stacks.iop.org/0004-637X/784/i=2/a=110.

Marchis, F., et al. (2006). Shape, size and multiplicity of main-belt asteroids: I. Keck adaptive optics survey. *Icarus, 185*(1), 39-63. Retrieved from: http://www.sciencedirect.com/science/article/B6WGF-4KKFPFC-1/2/ae7bcdf698fb09d108050779685ccceb.

Marks, P. (2012). Space booty. *New Scientist, 214*(2867), 28-29.

Mathurin, J., & Peter, N. (2006). Private equity investments beyond Earth orbits: Can space exploration be the new frontier for private investments? *Acta Astronautica, 59*(1–5), 438-444.

McCready, S. (2005). TCO, NPV, EVA, IRR< ROI: Getting the terms right. *CIOview, 0*(0), 1-7.

McKay, D. S., Duke, M. B., & McKay, M. F. (1992). Space resources. Volume 3: Materials *NASA-SP-509-VOL-3*: NASA Johnson Space Center.

Nathan, S. (2012). Asteroid mining: Disaster movie, or the shape of things to come? (Vol. 297).

O'Leary, B., Gaffey, M. J., Ross, D. J., & Salkeld, R. (1979). *Retrieval of asteroidal materials:* Retrieved from https://settlement.arc.nasa.gov/spaceres/IV-2.html. Moffett Field, CA: NASA Ames Research Center.

Phillips, T. (Producer). (2013, March 10, 2015). Ten thousandth near Earth object discovered. *NASA Science News*. Retrieved from http://science.nasa.gov/science-news/science-at-nasa/2013/24jun_neo/.

Pop, V. (2000). Appropriation in outer space: the relationship between land ownership and sovereignty on the celestial bodies. *Space Policy, 16*(4), 275-282.

Porter, M. E. (2008). The five competitive forces that shape strategy. *Harvard Business Review* (January 2008), 86-104.

Reynolds, G. H. (2013). Staking a claim: go to space, young man. Asteroid mining is the future, and the law's on your side! *Popular Mechanics, 190*(4), 50.

Rogoff, H. (2015). *Elements of a business case*. NetWorth Consulting. Bethesda, MD.

Ross, S. D. (2001). *Near-Earth asteroid mining*. Pasadena, CA: California Institute of Technology. Retrieved from http://www.nss.org:8080/settlement/asteroids/NearEarthAsteroidMining(Ross2001).pdf.

Salzmann, O., Ionescu-Somers, A., & Steger, U. (2005). The business case for corporate sustainability: Literature review and research options. *European Management Journal, 23*(1), 27-36.

Sanchez, J. P., & McInnes, C. (2011). Asteroid Resource Map for Near-Earth Space. *Journal of Spacecraft and Rockets, 48*(1), 153-165.

Sharma, N., & Mahajan, A. (2013). Lakshita – Mining and research hub at L5. *Advances in Space Research, 52*(6), 1063-1071.

Shaw, L. E. (2013). Asteroids, the new Western frontier: applying principles of the General Mining Law of 1872 to incentivize asteroid mining. *Journal of Air Law and Commerce, 78*(1), 121-169.

Slezak, M. (2013). Space miners hope to build first off-Earth economy. *New Scientist, 217*(2906), 8-10.

Sonter, M. J. (1997). The technical and economic feasibility of mining the near-earth asteroids. *Acta Astronautica, 41*(4–10), 637-647.

Sonter, M. J. (2001). Near Earth Objects as resources for space industrialization. *Solar System Development Journal, 1*(1), 1-31.

Stewart, D. (2015). Chemicool. Retrieved from: http://www.chemicool.com/.

Tardivel, S., Takahashi, Y., Zimmer, A. K., Herman, J. F. C., Reijneveld, J. P. J., Dunlop, K. L., & Scheeres, D. J. (2015). Human exploration of near Earth Asteroids: Architecture of proximity operations. *Acta Astronautica, 110*(0), 18-28.

Tedesco, E. F., Cellino, A., & Zappalà, V. (2005). The statistical asteroid model: The main belt population for diameters greater than 1 kilometer. *Astronomical Journal, 129*, 2869-2886.

Tronchetti, F. (2014). Private property rights on asteroid resources: Assessing the legality of the ASTEROIDS Act. *Space Policy, 30*(4), 193-196.

Webster, I. (2015). Asterank. Retrieved from: http://www.asterank.com/.

Wheeler, D., & Sillanpää, M. (1998). Including the stakeholders: The business case. *Long Range Planning, 31*(2), 201-210.

Wibben, D. R., & Furfaro, R. (2015). Model-based systems engineering approach for the development of the science processing and operations center of the NASA OSIRIS-REx asteroid sample return mission. *Acta Astronautica, 115*, 147-159.

Zimmer, A. K., & Messerschmid, E. (2011). Going beyond: Target selection and mission analysis of human exploration missions to Near-Earth Asteroids. *Acta Astronautica, 69*(11–12), 1096-1109.

Zimmerman, D., Wagner, S., & Wie, B. (2015). *The first human asteroid mission: Target selection and conceptual mission design*. Paper presented at the AIAA/AAS Astrodynamics Specialist Conference, Toronto, ON.

Appendices

Appendix A.: Hypothetical One Kilometer Metallic Asteroid Valuation - Today's Market Prices[*]

	1KM Metallic Asteroid Example - Full Production - Today's Market Prices							
	Market Price ($/KG)	Low Si Concentration Mine Capacity (Tons/Yr)	High Si Concentration Mine Capacity (Tons/Yr)	% Sold to Earth	Low Si Case Est. Sales/ Yr ($B)	High Si Case Est. Sales/ Yr ($B)	Est. Total Opportunity Low Si Case ($T)	Est. Total Opportunity High Si Case ($T)
Cobalt (Co)	27.5	791944.5	201460.2	100%	19.8	5.0	9.9	2.5
Platinum Group Metals (PGM)								
Platinum (Pt)	49000	11.1	122.8	100%	0.5	5.5	0.2	2.7
Palladium (Pd)	24100	253.4	157.4	100%	5.5	3.4	2.8	1.7
Osmium (Os)	12900	4.8	129.1	100%	0.1	1.5	0.0	0.8
Iridium (Ir)	25700	63.4	125.9	100%	1.5	2.9	0.7	1.5
Rhodium (Rh)	36200	15.8	53.5	100%	0.5	1.8	0.3	0.9
Ruthenium (Ru)	2400	12.7	125.9	100%	0.0	0.3	0.0	0.1
Rhenium (Re)*	4600	0.6	10.4	100%	0.0	0.0	0.0	0.0
				TOTAL PGM	$8.1	$15.4	4.1	7.7
Semiconductors (SC)								
Phosphorous (P)	300	205905.6	4092.2	100%	56.0	1.1	28.0	0.6
Germanium (Ge)	1200	4.8	6295.6	100%	0.0	6.9	0.0	3.4
Gallium (Ga)	2666	23.8	273.9	100%	0.1	0.7	0.0	0.3
Indium (Ir)	745	1.6	0.8	100%	0.0	0.0	0.0	0.0
Arsenic (As)	3200	285.1	5.7	100%	0.8	0.0	0.4	0.0
Antimony (Sb)	4.44	53.9	1.1	100%	0.0	0.0	0.0	0.0
Selenium (Se)	50.3	1267.1	166.8	100%	0.1	0.0	0.0	0.0
Tellurium (Te)	4.44	0.0	21.7	100%	0.0	0.0	0.0	0.0
				TOTAL SC	$57.0	$8.7	28.5	4.3
Precious Metals (PM)								
Gold (Au)	38000	79.2	1.6	100%	2.7	0.1	1.4	0.0
Silver (Ag)	5700	72.9	1.4	100%	0.4	0.0	0.2	0.0
				TOTAL PM	3.1	0.1	1.6	0.0
Silicon (Si)	1.4	0.0	786954.0	5%	0.0	0.0	0.0	0.0
				Grand Total	$68.2	$24.2	34.1	12.1

[*] Actual market pricing data obtained from Chemicool.com (Webster, 2015). Mineral concentration data obtained from (Lewis, 2015; Ross, 2001).

Appendix B: Hypothetical One Kilometer Metallic Asteroid Valuation - Artificially Cratered Market Prices[†]

1KM Metallic Asteroid Example - Full Production - Fluctuating Market Prices										
	Today's Price ($/KG)	% Price Fluctuation	Adjusted Price ($/KG)	Low Si Concentration Mine Capacity (Tons/Yr)	High Si Concentration Mine Capacity (Tons/Yr)	% Sold to Earth	Low Si Case Est Sales/ Yr ($B)	High Si Case Est Sales/ Yr ($B)	Est. Total Opportunity Low Si Case ($T)	Est. Total Opportunity High Si Case ($T)
Cobalt (Co)	27.5	-50.00%	13.75	791944.5	201460.2	100%	9.9	2.5	4.9	1.3
Platinum Group Metals (PGM)										
Platinum (Pt)	49000	-80.00%	9800	11.1	122.8	100%	0.1	1.1	0.0	0.5
Palladium (Pd)	24100	-80.00%	4820	253.4	157.4	100%	1.1	0.7	0.6	0.3
Osmium (Os)	12900	-80.00%	2580	4.8	129.1	100%	0.0	0.3	0.0	0.2
Iridium (Ir)	25700	-80.00%	5140	63.4	125.9	100%	0.3	0.6	0.1	0.3
Rhodium (Rh)	36200	-80.00%	7240	15.8	53.5	100%	0.1	0.4	0.1	0.2
Ruthenium (Ru)	2400	-80.00%	480	12.7	125.9	100%	0.0	0.1	0.0	0.0
Rhenium (Re)	4600	-80.00%	920	0.6	10.4	100%	0.0	0.0	0.0	0.0
						TOTAL PGM	$1.6	$3.1	0.8	1.5
Semiconductors (SC)										
Phosphorous (P)	300	-50.00%	150	205905.6	4092.2	100%	28.0	0.6	14.0	0.3
Germanium (Ge)	1200	-50.00%	600	4.8	6295.6	100%	0.0	3.4	0.0	1.7
Gallium (Ga)	2666	-50.00%	1333	23.8	273.9	100%	0.0	0.3	0.0	0.2
Indium (Ir)	745	-50.00%	372.5	1.6	0.8	100%	0.0	0.0	0.0	0.0
Arsenic (As)	3200	-50.00%	1600	285.1	5.7	100%	0.4	0.0	0.2	0.0
Antimony (Sb)	4.44	-50.00%	2.22	53.9	1.1	100%	0.0	0.0	0.0	0.0
Selenium (Se)	50.3	-50.00%	25.15	1267.1	166.8	100%	0.0	0.0	0.0	0.0
Tellurium (Te)	4.44	-50.00%	2.22	0.0	21.7	100%	0.0	0.0	0.0	0.0
						TOTAL SC	$28.5	$4.3	14.2	2.2
Precious Metals (PM)										
Gold (Au)	38000	-10.00%	34200	79.2	1.6	100%	2.5	0.0	1.2	0.0
Silver (Ag)	5700	-10.00%	5130	72.9	1.4	100%	0.3	0.0	0.2	0.0
						TOTAL PM	$2.80	$0.1	1.4	0.0
Silicon (Si)	1.4	0.00%	1.4	0.0	786954.0	5%	0.0	0.0	0.0	0.0
						Grand Total	$32.9	$7.5	16.5	3.8

[†] Actual market pricing data obtained from Chemicool.com (Webster, 2015) and adjusted downward to reflect crashed market. Mineral concentration data obtained from (Lewis, 2015; Ross, 2001).

Appendix C: Hypothetical Kilometer Metallic Asteroid Valuation – 1,000 Tons of PGMs Mined‡

1KM Metallic Asteroid Example - 1000 tons of PGM's Produced Annually - Today's Market Prices								
	Market Price ($/KG)	Low Si Concentration Mine Capacity (Tons/Yr)	High Si Concentration Mine Capacity (Tons/Yr)	% Sold to Earth	Low Si Case Est. Sales/ Yr ($B)	High Si Case Est. Sales/ Yr ($B)	Est. Total Opportunity Low Si Case ($T)	Est. Total Opportunity High Si Case ($T)
Cobalt (Co)	27.5	791944.5	201460.2	0%	0.0	0.0	0.0	0.0
Platinum Group Metals (PGM)								
Platinum (Pt)	49000	11.1	122.8	1%	0.0	0.1	0.0	0.0
Palladium (Pd)	24100	253.4	157.4	1%	0.1	0.0	0.0	0.0
Osmium (Os)	12900	4.8	129.1	1%	0.0	0.0	0.0	0.0
Iridium (Ir)	25700	63.4	125.9	1%	0.0	0.0	0.0	0.0
Rhodium (Rh)	36200	15.8	53.5	1%	0.0	0.0	0.0	0.0
Ruthenium (Ru)	2400	12.7	125.9	1%	0.0	0.0	0.0	0.0
Rhenium (Re)*	4600	0.6	10.4	1%	0.0	0.0	0.0	0.0
				TOTAL PGM	$0.1	$0.2	0.0	0.1
Semiconductors (SC)								
Phosphorous (P)	300	205905.6	4092.2	100%	56.0	1.1	28.0	0.6
Germanium (Ge)	1200	4.8	6295.6	100%	0.0	6.9	0.0	3.4
Gallium (Ga)	2666	23.8	273.9	100%	0.1	0.7	0.0	0.3
Indium (Ir)	745	1.6	0.8	100%	0.0	0.0	0.0	0.0
Arsenic (As)	3200	285.1	5.7	100%	0.8	0.0	0.4	0.0
Antimony (Sb)	4.44	53.9	1.1	100%	0.0	0.0	0.0	0.0
Selenium (Se)	50.3	1267.1	166.8	100%	0.1	0.0	0.0	0.0
Tellurium (Te)	4.44	0.0	21.7	100%	0.0	0.0	0.0	0.0
				TOTAL SC	$57.0	$8.7	28.5	4.3
Precious Metals (PM)								
Gold (Au)	38000	79.2	1.6	100%	2.7	0.1	1.4	0.0
Silver (Ag)	5700	72.9	1.4	100%	0.4	0.0	0.2	0.0
				TOTAL PM	3.1	0.1	1.6	0.0
Silicon (Si)	1.4	0.0	786954.0	5%	0.0	0.0	0.0	0.0
				Grand Total	$60.2	$8.9	30.1	4.5

‡ Actual market pricing data obtained from Chemicool.com (Webster, 2015). Mineral concentration data obtained from (Lewis, 2015; Ross, 2001).

Appendix D: Asteroid Mining Cost Model Detail Years 1-10

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Wages/Benefits	6000000	6600000	7260000	7986000	8784600	9663060	10629366	11692302.6	12861532.86	14147686.15
Growth Rate	0	10%	10%	10%	10%	10%	10%	10%	10%	10%
Facilities	850000	850000	850000	850000	1700000	1700000	1700000	5100000	5100000	5100000
Growth Rate	0	0	0	0	100%	0	0	200%	0	0
Launch Costs	110000	440000	880000	1320000	400000000	0	400000000	0	1000000000	1000000000
Growth Rate	0	300%	100%	50%	0%	-100.00%	0%	0%	0%	0%
Project Costs	300000	1248000	2496000	3744000	1000000	0	1040000	0	1081600	1124864
Growth Rate	0	4%	4%	4%	0%	0%	4%	0%	4%	4%
Space HDW/SW	30000000	120000000	240000000	360000000	1000000000	0	1000000000	0	1500000000	1500000000
Growth Rate	0	300%	100%	50%	0%	-100.00%	0%	0%	0%	0%
R & D	5000000	5000000	5000000	5000000	5000000	10000000	2500000	2500000	2500000	2500000
Growth Rate	0	0	0	0	0%	100%	-75%	0%	0%	0%
Ops & Maint	422600	1341380	2564860	2564860	212472690	3204459	212380404.9	2893845.39	378231469.9	378430882.5
Constant Rate										
Insurance	300000	1200000	2400000	3600000	4000000	0	4000000	0	10000000	10000000
Constant Rate										
Sales & Marketing	429826	1366793.861	2614508.621	3850648.611	16329572.91	245675.181	16322497.7	221861.5009	29097746.03	29113034.33
Contant Rate										
Legal	214913	683396.9307	1307254.311	1925324.306	8164786.456	122837.5905	8161248.851	110930.7505	14548873.01	14556517.16
Constant Rate										
Total	$43,627,339.00	$138,729,570.79	$265,372,622.93	$390,840,832.92	$1,657,451,649.37	$24,936,031.77	$1,656,733,517.45	$22,518,940.24	$2,953,421,221.83	$2,954,972,984.16
$(B)	0.04	0.14	0.27	0.39	1.66	0.02	1.66	0.02	2.95	2.95

Appendix E: Asteroid Mining Cost Model Detail Years 11-20

	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Wages/Benefits	15562454.76	17118700.24	18830570.26	20713627.29	22784990.01	25063489.02	27569837.92	30326821.71	33359503.88	36695454.27
Growth Rate	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Facilities	10200000	10200000	10200000	10200000	10200000	10710000	10710000	10710000	10710000	10710000
Growth Rate	100%	0	0	0	0	5%	0	0	0	0
Launch Costs	1000000000	1000000000	1000000000	1000000000	0	0	0	0	0	0
Growth Rate	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Project Costs	1169858.56	1216652.902	1265319.018	1315931.779	0	0	0	0	0	0
Growth Rate	4%	4%	4%	4%	0%	0%	0%	0%	0%	0%
Space HDW/SW	1500000000	1500000000	1500000000	1500000000	0	0	0	0	0	0
Growth Rate	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
R & D	2500000	2500000	2500000	2500000	2500000	2500000	2500000	2500000	2500000	2500000
Growth Rate	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Ops & Maint	379414847	379655303	379919383.4	380209433.9	5322748.502	5741023.352	6116975.688	6530523.256	6985425.582	7485818.14
Constant Rate										
Insurance	10000000	10000000	10000000	10000000	0	0	0	0	0	0
Constant Rate										
Sales & Marketing	29188471.61	29206906.56	29227152.73	29249389.93	408077.3862	440145.1252	468968.1371	500673.4507	535549.2956	573912.7251
Contant Rate										
Legal	14594235.81	14603453.28	14613576.36	14624694.97	204038.6931	220072.5626	234484.0685	250336.7253	267774.6478	286956.3625
Constant Rate										
Total	$2,962,629,867.74	$2,964,501,015.95	$2,966,556,001.76	$2,968,813,077.82	$41,419,854.60	$44,674,730.06	$47,600,265.81	$50,818,355.14	$54,358,253.41	$58,252,141.50
$(B)	2.96	2.96	2.97	2.97	0.04	0.04	0.05	0.05	0.05	0.06

Appendix F: Asteroid Mining Cost Model Detail Years 21-25

	Year 21	Year 22	Year 23	Year 24	Year 25
Wages/Benefits	40364999.7	44401499.67	48841649.63	53725814.6	59098396.05
Growth Rate	10%	10%	10%	10%	10%
Facilities	10710000	10710000	10710000	10710000	10710000
Growth Rate	0	0	0	0	0
Launch Costs	0	0	0	0	0
Growth Rate	0%	0%	0%	0%	0%
Project Costs	0	0	0	0	0
Growth Rate	0%	0%	0%	0%	0%
Space HDW/SW	0	0	0	0	0
Growth Rate	0%	0%	0%	0%	0%
R & D	1000000	1000000	1000000	1000000	1000000
Growth Rate	0%	0%	0%	0%	0%
Ops & Maint	7811249.954	8416724.95	9082747.445	9815372.189	10621259.41
Constant Rate					
Insurance	0	0	0	0	0
Constant Rate					
Sales & Marketing	598862.4975	645282.2472	696343.9718	752511.8688	814296.5556
Contant Rate					
Legal	299431.2488	322641.1236	348171.9859	376255.9344	407148.2778
Constant Rate					
Total	$60,784,543.40	$65,496,147.99	$70,678,913.03	$76,379,954.59	$82,651,100.30
$(B)	0.06	0.07	0.07	0.08	0.08

Appendix G: Asteroid Mining Revenue Base Case Model Years 1-10

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Services TCV ($M)	$10.00	$13.00	$16.90	$21.97	$28.56	$34.27	$41.13	$49.35	$59.22	$71.07
Annual Growth Rate	30%				20%					10%
Annual Ore Production (K Tons)	0	0	0	0	0.1	1	4	16	64	256
Production Rate	0.00%	0.00%	0.00%	0.00%	0.01%	0.10%	0.40%	1.60%	6.40%	25.60%
Annual Revenue Yield ($B)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
PGMs	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00	$0.01	$0.02
Semiconductors	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.03	$0.14	$0.55	$2.22
Precious Metals	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.01	$0.05	$0.20	$0.80
Nickel	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00	$0.01	$0.06
Cobalt	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.00	$0.00	$0.00	$0.01
Mining Total ($B)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$0.2	$0.8	$3.1
Revenue Total ($B)	$0.01	$0.01	$0.02	$0.02	$0.03	$0.05	$0.09	$0.24	$0.83	$3.17

Appendix H: Asteroid Mining Revenue Base Case Model Years 11-20

	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
Services TCV ($M)	$71.07	$78.18	$85.99	$94.59	$104.05	$114.46	$123.61	$133.50	$144.18	$155.72	$168.18
Annual Growth Rate	10%					8%					
Annual Ore Production (K Tons)	256	512	640	704	800	1000	1000	1000	1000	1000	1000
Production Rate	25.60%	51.20%	64.00%	70.40%	80.00%	100%	100%	100%	100%	100%	100%
Annual Revenue Yield ($B)	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20
PGMs	$0.02	$0.04	$0.05	$0.06	$0.06	$0.08	$0.08	$0.08	$0.08	$0.08	$0.08
Semiconductors	$2.22	$4.43	$5.54	$6.09	$6.92	$8.65	$8.65	$8.65	$8.65	$8.65	$8.65
Precious Metals	$0.80	$1.59	$1.99	$2.19	$2.49	$3.11	$3.11	$3.11	$3.11	$3.11	$3.11
Nickel	$0.06	$0.11	$0.14	$0.15	$0.17	$0.22	$0.22	$0.22	$0.22	$0.22	$0.22
Cobalt	$0.01	$0.02	$0.03	$0.03	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Mining Total ($B)	$3.1	$6.2	$7.7	$8.5	$9.7	$12.1	$12.1	$12.1	$12.1	$12.1	$12.1
Revenue Total ($B)	$3.17	$6.28	$7.83	$8.62	$9.79	$12.22	$12.23	$12.24	$12.25	$12.26	$12.27

Appendix I: Asteroid Mining Revenue Base Case Model Years 21-25

	Year 21	Year 22	Year 23	Year 24	Year 25
Services TCV ($M)	$181.63	$196.16	$211.85	$228.80	$247.10
Annual Growth Rate					
Annual Ore Production (K Tons)	1000	1000	1000	1000	1000
Production Rate	100%	100%	100%	100%	100%
Annual Revenue Yield ($B)	Year 21	Year 22	Year 23	Year 24	Year 25
PGMs	$0.08	$0.08	$0.08	$0.08	$0.08
Semiconductors	$8.65	$8.65	$8.65	$8.65	$8.65
Precious Metals	$3.11	$3.11	$3.11	$3.11	$3.11
Nickel	$0.22	$0.22	$0.22	$0.22	$0.22
Cobalt	$0.04	$0.04	$0.04	$0.04	$0.04
Mining Total ($B)	$12.1	$12.1	$12.1	$12.1	$12.1
Revenue Total ($B)	$12.29	$12.30	$12.32	$12.33	$12.35

On Bored to Mars

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ABSTRACT - The next great exploratory step in the story of our species will come to fruition on the day that one representative of humankind first physically steps onto the red planet. In theory, the majority of physical barriers that stand between us and this watershed event are soluble. Even our contemporary technologies have placed robotic explorers on Mars; and thus, in principle, there are few prospective showstoppers that would absolutely defeat a human mission. Here, such physical limitations that threaten mission success are not featured. Rather, the present emphasis is on the psychological constraints that must be overcome if our failure-intolerant society is to sufficiently support this vital, species-altering enterprise.

"The majority of the flight will be automated which reduces task-load for the teams but that leaves nothing for them to do and that's the worst thing that could happen." (Astronaut Interview)[1]

I. Introduction

In our contemporary world, explorations of space do not seem to spark and fire the imagination in the same manner they once did in the heyday of the early nineteen-sixties. The inspirational achievements of the manned Mercury, Gemini, and Apollo missions now seem far removed and remote, at least from the two generations that have grown up since that apparent apotheosis of human-piloted spaceflight. In our contemporary world, we are more likely to encounter the thrills of space via Hollywood's illusions as opposed to those heady days when early color televisions were dominated by liftoffs and splashdowns. Why is this? Today, many people rightly inquire whether we do not have troubles aplenty here on planet Earth. Do we really need to spend scarce resources sending a limited number of highly selected human experts to perform arcane scientific evaluations on distant lumps of rock? The simple answer is – yes, we do! The very future of our species lies in its expansive elaboration (Hancock, 2009a). If we give up on space exploration, we give up on ourselves. Many and diverse reasons have been offered for the continued importance of human space exploration. These reasons range from highly spiritual aspirations (see Reinerman-Jones et al., 2013), to extremely practical concerns, where the latter very much lie at the heart of

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[1] Astronaut Interview on file with author.

the coming wave of commercial space exploitation (and see also Hubbard, 2011). However, regardless of the morality of, or the source of the impetus for the pursuit of such activity, the simple fact is that humans are an explorative species. So, curtailing that expansion would represent a telling symptom of its prospective demise. Even if it is only to further understand the world we live in (see Lovelock, 1979), into space we must go!

That being said, the general vector of modern society, especially in our western world, is toward an ever-more risk averse social stance as, for example, our attitude towards casualties in modern warfare clearly demonstrates (Coker, 2009). Consequently, any mission designed to achieve Martian occupation (see Figure 1) must live within these normative levels of social risk expectation. At once, this raises an essential dissonance. Space travel is, by its very nature, inherently dangerous. Missions that necessarily break new ground (as it were) are even more fraught with uncertainty. While those who are destined to go on these journeys readily accept and even embrace such levels of risk (and see the “Mars to Stay” proposals), the greater mass of society who must support their efforts are grounded in Hollywood’s necessary narrative of untrammeled success. Essentially, in almost all representations of our travels to the red planet, the storyline includes severe challenges but the resolution always concludes with human triumph. This cultivated social level of risk perception, and the implicit and explicit promise of success, serves as a predicate to all subsequent profiles of progress. Thus, future missions, such as that to Mars are ring-fenced by procedures such as formal risk assessments, detailed simulations, mission projections, extensive personnel training, and the like. These are all designed to reduce the nominal level of risk (i.e., our best educated guess at the inherent failure rate). These formal and quasi-mathematical estimates must be reconciled to the risk level that represents a collective degree of comfort. Such comfort must extend from the proximal institutional administrators who are responsible for mission completion, out to the wider social community. Whether these putatively quantitative assessments are valid or whether they are even underpinned by any rational philosophical foundation whatsoever is the subject of much current debate (see e.g., Dekker, Hancock, & Wilkin, 2013; Hollnagel, 2014). Regardless of these fundamental and foundational disputes, long-duration, non-near-Earth (NNE), or deep-space explorations are inherently fraught with peril. It is one particular and potentially hidden form of such peril that is discussed and featured in the present work. This is, the issue of boredom.

a. An Esoteric Rate-limiting Factor?

On its head, this seems rather a strange concern. After all, isn’t space exploration almost the epitome of excitement? As we shall see, it is perhaps this initial reaction that hides the dangers of boredom that lurk within. After all, both initial exploration and subsequent colonization are each driven by a search for opportunity, where the excitement of that search is often anodyne to boredom itself (Hancock, 2017a). Prior to humans first being launched into space, perhaps the primary initial concern was whether any living entity could simply sustain the inherent stresses that would be encountered. As is evident from much early work, this question over the viability of any living system in space was one that much-tasked early pioneers.[2] The fundamental empirical challenge for this outreach beyond our planet’s surface was, and still to a degree remains, sheer survival. In

[2] Gary, T. (2004). A brief history of animals in space. Retrieved May 21, 2017, from http://history.nasa.gov/animals.html. February 20, 1947 - fruit flies; June 11, 1948 - Albert I, a rhesus monkey; August 31, 1950 - first mouse in space; July 22, 1951 - "Tsygan" and "Dezik" first dogs in space; January 31, 1961; April 12, 1961: Yuri Gagarin.

respect of physiological survival, there grew a cadre of specialists in space physiology founded upon the extant medical knowledge of military and research flight surgeons who had asked the same basic question about aviation itself, largely following upon the first developments of powered flight. It has been popular to denigrate the role of the space-flight surgeon. For example, in movie representations such as *The Right Stuff* (1983) and *Apollo 13* (1995) we witness this implicit diminution. Often, these latter individuals are portrayed as naysayers and as obstructions to be faced and overcome by the go-getting, can-do members of the team. However, in reality, these individuals remain vitally contributing professionals whose basic mandate is to keep the astronaut alive; and thus, this mandate must be reinforced and respected at all stages.

Figure 1: A leitmotif for human exploration of Mars. The epithet "Boots on the Ground" emphasizes the imperative for human exploration and human presence on the planet itself (graphic by the author).

These specialized personnel keep astronauts functioning in inherently life-threatening, life-negating circumstances. Based in the culture of the general medical profession, space physiology research has, and still does, necessarily emphasize the physiological dimensions of response.[3] How can it not? In the early traditions of such work, one central notion was that of *physiological adequacy*. This informal proposition assumed that while physiological homeostasis remained undisturbed, work performance capacity itself also stayed acceptably stable. Today, we know that this is not true and indeed is demonstrably false (and see Hancock, 1982; Hancock & Warm, 1989). So, it is necessary to understand how the stresses of space exploration affect both the physiological

[3] Interestingly, this may well be changing as might be inferred in the name change of the flagship journal of the Aerospace Medical Association (AsMA) from its former, *Aviation, Space, and Environmental Medicine*, to now, *Aerospace Medicine and Human Performance*. Time will tell how profound such a change actually is. Regardless, aerospace medicine still remains the domain primarily of medical doctors who are Board certified in the specialty.

as well as the psychological dimensions of astronaut well-being and responsivity. The fact that such physiological states and psychological capacities prominently interact with each other has also not escaped contemporary scrutiny (e.g., Kanas, 2015; Marras & Hancock, 2013).

So, although the sustenance of life is a necessary pre-condition for human mission success, alone, it is neither a sufficient nor an exclusive requirement. The reason why humans must go and follow upon their robotic predecessors in exploration is because of the fundamental nature of the human psyche. We require that human consciousness be present, even if those persons actually on the red planet represent only a proxy for the rest of us. Thus, efficient and effective psychological functioning is actually the principal *raison d'etre* for all human-piloted space missions. We are really all about putting a healthy, functioning brain on Mars. However, to a degree, these central and crucial psychological capacities and resiliencies still remain a somewhat esoteric constraint to many in the space engineering community. This is also true for the overall populace in general when they envisage Mars exploration. But just as cognition is necessarily embodied (Clark, 1998), so must our presence on other worlds be embodied also; even if that means we still have to see those new worlds through surrogate human eyes. Our human aspiration does not require that *all* human beings be present on Mars, but it certainly requires a sample of at least one or more of us to be physically there if we are to experience the empathic human dimensions of excitement (and see Hancock, 2015).

b. The Journey to Mars – Hollywood Style

We can learn much of any conceived mission to Mars from the admittedly gross and largely illusory simulations that are represented through the somewhat slanted conceptions generated by science fiction novelists and Hollywood script-writers. However, we should not underestimate the degree to which Hollywood drives technical expectations. For example, the expressed desire for an actual *Iron Man* form of ordnance for the U.S. Army seems to have been derived from the Marvel Comic and its associated movies [2008, 2010, and 2013] (Magnuson, 2015; *Wall Street Journal*, 2014).[4] Another appropriate example comes from the way visual conceptions have driven the public perception of robots and this, in turn, has affected subsequent technical designs and innovation paths (see Schaefer, Adams, Cook, Bardwell-Owens, & Hancock, 2015). We are all aware of procurement officials who long for operational systems that they have first encountered via the big screen and the magic of Hollywood with its enabling capacities of computer-generated imagery (CGI). Such aspirations may be laudable but are often misdirected. What many, if not essentially all, of these fictional representations of the Mars mission feature are the high excitement, high workload, off-nominal events in which our heroic astronauts (actors) struggle mightily and intensely to resolve the unanticipated, emergency demands (and of course ultimately successfully do so). One can insert almost any of the modern movies as examples here but again *Red Planet* (2000) and *Mission to Mars* (2000) are more than adequate representations. Even *Apollo 13,* which recapitulates the reality of a trip to the Moon, fits this form of narrative in which the extended periods of rote activity are simply dispensed with. I anticipate that future film peers will,

[4] Of course, we must recognize that even the notion of an “Iron Man” itself derives from earlier incarnations of armored knights who sought to use the then highest state of the art to provide maximal protection in combat. The technology at that time was equally as costly and only open to the very richest in society.

assumedly, follow exactly upon this narrative protocol[5]. We experience the excitement of launch and then leap immediately to the next mission highlight such as insertion into Mars orbit. We float insensibly over the vast intervals of time and space between these epochs of high activity. But in Hollywood this lacuna is quite natural and understandable, for in the entertainment world, patrons do not want to have to sustain their attention to drab, unvarying, uninteresting and frankly boring scenes for extended periods of time; such movies tank. However, in the real world, this extensive period of chronic underload has to be tolerated (and perhaps also exploited). In actuality, this under-loaded phase of the mission to Mars represents a significant, if largely unacknowledged, barrier to success, as I shall explore and articulate here.

Boredom frequently arises from extended periods of insufficient stimulation, often taking the form of repetitive tasking or indeed no imperative tasks at all. We can, of course, keep astronauts "busy" with a variety of "necessary" tasks. Rote performance requirements such as vehicle maintenance and monitoring, long-duration space flight (LDSF) experimentation, and on-going mission assessment and potential course corrections can take up the time of human astronauts. However, as we shall see, many of these routine requirements can and will be the target of automation. Indeed, with this general propensity to allow automation to penetrate all human occupational worlds, momentary vehicle control and indeed many other vital systemic processes will necessarily be handed over to the machine (and see Hancock, 2014, 2017b). A later section of the present work focuses explicitly on these issues of automation, autonomy, and robotics. Problematically, automation frequently (and perhaps ubiquitously) leaves the human in the unenviable role of system monitor (Hancock, 2013). When displays are poorly conceived, designed, and constructed, this monitoring role places human operators in a most parlous situation. This is because it is the human who is tasked with recovering a progressively less stable system and has progressively less time in which to do so. In these invidious circumstances, the humans then become the apocryphal *subsystem of last resort*. Such demand oscillations are connoted by what have been termed, "hours of boredom and moments of terror" (and see Hancock & Krueger, 2010). It is the initial precursors to these precarious and unstable epochs of wildly varying demand that are now examined. The first and deceptively simple issue is: what is boredom? (and see Smith, 1981).

II. All Aboard or All Are Bored?

Boredom is a sly and silent killer. Like all clever assassins, boredom exerts its influence indirectly through proxies and intermediaries, rarely ever exposing itself to be identified as the prime suspect in failure and disaster. But like its close cousin, fatigue, boredom is nevertheless a pre-potent force that can have subtle yet devastating effects, especially over the long term. Nothing characterizes this "long term" more than the envisaged months and even years representing the round trip to Mars (Kanas, 2011). Boredom has a long history in psychological research (see Barmack, 1937; Davies, Shackleton, & Parasuraman, 1983), including contributions by the influential, and yet so aptly named, psychologist Edwin Boring (see Stevens, 1973). Boredom arises as a consequence of chronic under-stimulation or underload occasioned by unvarying environmental conditions. The latter circumstances encourage excessive homogeneity in both the individual's range

[5] This article was first written and submitted prior to release of *The Martian*. It is gratifying to see that the prognostication as to what the moviemakers would feature, and especially what they would not feature, was in fact confirmed in the final 2015 production.

of perception and action. Thus, boredom and lassitude prove close companions, while work complacency follows closely behind (Parasuraman & Manzey, 2010). However, like the appraisal processes associated with stress (see Hancock & Warm, 1989; Lazarus & Folkman, 1984), there are large individual differences among people as to how the same environment is assessed as being unvarying and, as a consequence, boredom-inducing (Hill, 1975). So, while we typically conceive of boredom as ubiquitously an adverse condition, this need not necessarily be so (and see Suedfeld, 1975). Like many associated energetic states, we each know boredom when we experience it, but the profile of its various antecedents is not always determined or stable, and therefore boredom can arise from a number of differing precursors. Despite the population-based differences, and thus an inherent variability in human susceptibility to boredom (Thackray, 1981; Thompson, 1929), we can and should anticipate that objective levels of such underload will be a characteristic hallmark of all human deep-space exploration, including the mission to Mars.

It is of value here to link boredom to the allied construct of fatigue (and see Matthews, Desmond, Neubauer, & Hancock, 2012). Desmond and Hancock (2001) looked to parse fatigue beyond the classical physical versus cognitive differentiation. The latter authors proposed that fatigue might arise in two distinct forms, i.e., either *active* or *passive* fatigue. Active fatigue derives from repeated actions; that is, doing the same thing over and over again for an extended period of time. Clearly, such actions themselves can be either predominantly physical or cognitive in nature (but see also Marras & Hancock, 2013). Thus, repeating some pre-set action sequence again and again is a recipe for active fatigue and exposes the human flaw in work strategies epitomized by Tayloristic, time-and-motion approaches. However, a second form of fatigue occurs because people are constrained to be manifestly *inactive*. Watching impoverished and uninteresting displays of automatic functioning for extremely rare signals, as encountered in vigilance, is highly related to these "passive" antecedents of fatigue (Hancock, 2013). While boredom and active fatigue in general frequently co-vary, the link between boredom and passive fatigue is the stronger of the two.

Given this window on passivity, there are certain strategies that we can enact in order to pre-combat this looming issue of boredom. Some have proposed strategies for dealing with boredom preemptively through crew selection and planned mission support (Kanas, 2011). The premise upon which we have to base any such attack is a bespoken one.[6] However, our population with respect to the crew for Mars or any deep-space mission is fundamentally very small. With such a specialized population, applied researchers in psychology need to move from a general nomothetic mindset to an individualized, idiographic approach. In another work, we have termed this latter enterprise *individuation* (Hancock, Hancock, & Warm, 2009). Deep-space exploration is perhaps the modal realm for the innovative application of this notion of individuation, as indeed flight has generally been throughout its existence. As we begin to recast our terminology and move from labels such as "automation" to "autonomy" and from "adaptation" to "resilience," we need to frame these evolutionary trends against this background of change from the general to the specific, from the group to the individual. With the continuing advances in computational power and the inter-linked capacity of modern portable technologies, we shall eventually see all research as population-based (as opposed to sample-based) as we experience the capacity to measure the responses

[6] Often, we create models and simulations with the purpose of inferring a general, nomothetic cognitive capacity (e.g., see the overall ACT-R architecture and its applications). Various curve-fitting approaches are then used to infer population-based behavior from the degree of fit to the recorded, sample-based data. This indeed is the traditional way we have approached many such problems and this leads to useful and comprehensive models such as IMPRINT.

of each and every human individual in a fully dynamic manner. Both inference and insight will radically change under such an evolution. After all, why try to predict an individual's response from a general model when you can assess that self-same person individually and on-line, as it were. One immediate application of this changing perspective lies in deep-space exploration.

For our astronauts, this time is already come. We need to create workload management systems that account for both chronic and acute forms of demand and, in particular, we must provide a meaningful and consistent level of challenge to mitigate the intrinsic and extensive periods of boring underload. Too often, applicable models of human operator capacity are directed to evaluating potential ceiling effects for overall response capacity, guarding against what will be ever-rarer intervals of overload. In the present circumstances, we must look more particularly at avoiding the inherent floor-effect that face our on-board personnel directly. It is, however, possible to argue that boredom per se is not an absolutely critical concern. So, what if astronauts are bored? Let them be bored, after all this condition surely just another testing part of the job! Sadly, this reasoning is specious. As I have noted elsewhere: *if we create circumstances in which people are rarely required to respond, they will rarely respond when required*. Nothing epitomizes this precursor to failure than the transition from very low to very high workload. Having looked, albeit briefly, at the basic state of boredom we now move to concerns for when boredom rapidly turns into incipient panic (and for a military context of such a transition see, Roach, 2016).

a. From Hours of Boredom and Moments of Terror to Months of Monotony and Milliseconds of Mayhem

People do not die of boredom per se. Rather they die as a result of the state of un-readiness which boredom induces. This is especially the case when they need to respond with dispatch and efficiency following the epochs of ennui and lassitude induced by boredom (and see Hancock, & Krueger, 2010). Boredom is a failure of the information foraging system (Pirolli, 2009; Pirolli & Card, 1999). It occurs because the surrounding environmental display lacks the diversity to engage the individual's active attentional processes. These attractors of attention are often identified as being related to stimulus intensity, stimulus novelty, and stimulus relevance as mediated by top-down perceived needs for task resolution. In today's information-congested (or even information-constipated) environments, we have witnessed the commodification of human attention such that we now encounter many "thieves of attention" all around us. Some of these we embrace, but others we sadly and necessarily cannot ignore (Hancock & Sawyer, 2015). However, these acts of larceny are embedded in highly stimulating worlds (Hancock, 2016). In the absence of all external stimuli, human beings begin to eat their own intrinsic informational stores. In acute forms, this can be transiently hedonic (as in reverie or daydreaming). However, in its chronic expression, this cognitive self-consumption can be vastly psychologically destructive (as in forms of enforced sensory and perceptual deprivation; and see Hancock, 1980).

The radical reduction of all sensory and perceptual stimulation has highly deleterious effects upon perception and cognition as well as subsequent decision-making. This was demonstrated in some of the earliest work in reported deprivation studies (see Zubek, 1969). Even when stimuli are not completely excised but just denuded of their meaningful pattern, the associated "perceptual" deprivation, while not so imminently destructive, eventually exerts comparable overall levels of degradation (Zubek, 1973). Inevitably, there will be intrinsic limits on the degree of environmental variability within the small-pressurized volume of the anticipated Mars spacecraft. The restorative function of expansive, outdoor "natural" environments will be largely unavailable (and see e.g., Hartig, Mang, & Evans, 1991). Personal and operational resilience will be compromised accordingly. The further down the scale of boredom-induced and depressed responsivity that we go, the less that the crew will be able to deal with unanticipated overload situations, if and when they occur. This propensity may even actually apply to anticipated high workload conditions also (e.g., planetary landing), although as yet we do not know if this will be the case. But we will need augmented training programs. So, for example, imagine an emergency close to mission completion during Earth re-entry, a phase that is anticipated in many current Mars mission scenarios. For some Mars mission profiles, this may mean that the crew need to exercise skills that have not been practiced for some years! Clearly, epochs of boredom can be alleviated with such en-route training episodes. Together with these short-term and anticipatable fluctuations in responsivity to imposed task load, there are a number of higher level cognitive concerns related to boredom that we have to acknowledge in order to ensure a safe and healthy crew experience. It is to one example of these higher concerns that we now turn by looking back into the past.

b. The Planetary "Break-off" Phenomenon

In the early days of jet-powered military aviation, an interesting phenomenon was reported concerning psychological reactions to those unprecedented operational conditions. This was known as the *break-off phenomenon*. It was characterized by Clark and Graybiel (1957) as "*a feeling of physical separation from the Earth experienced by jet aviators flying alone at high altitudes and relatively un-occupied with flight details*." This condition was exacerbated if the pilots were traveling above a low-level cloud deck or canopy that served to obscure their direct vision of the Earth below. Inevitably, given the operational parameters of such early, high-altitude aircraft, this experience was a necessarily transient one and could be sustained only for relatively brief intervals of time (although to some pilots the distortion of time also seemed intrinsic to that experience, and see Hancock & Carson, 1986). Further, it is wrong to characterize these break-off phenomena as ubiquitously adverse, since a number of pilots reported this as a condition of "blissful reverie." As with boredom itself, we are well advised in the behavioral sciences to eschew absolutes. In contrast to a blissful reverie, however, a considerable number of the 35% of all individuals who reported experiencing this state (i.e., some one third of those 35% of pilots) found that break-off induced unpleasant feelings of loneliness, anxiety, spatial disorientation, and even pseudo-hallucinations. These latter sets of experiences are not conducive for prolonged mission success. While it has been observed that such phenomenological experiences may well be mitigated by the presence of others (i.e., immediate social interaction), we have yet to engage in deep-space missions lasting over multiple years.[7] Such isolation, perhaps best expressed as a *planetary break-off phenomenon*, may well prove to be an important barrier to successful long-term exploration. In short, home will be a long way away and, on the trip to Mars, the Earth will eventually fade from a "pale blue dot" to merely one of the myriad of lights to be observed from the windows of the capsule. Thus, psychological barriers to mission completion do not all come in "canned" and traditional forms that we can, piecemeal anticipate as being able to be dealt with. Even if we possess

[7] It is the case that we have multiple Earth-bound and on-orbit analogs of potential, long-duration space missions. While such observations can begin to help us to understand some of the stresses and challenges of the proposed Mars mission, they are often far enough away from the latter reality that any transfer of their findings must necessarily be applied with great caution.

the ability to adapt to the physical stresses, it is highly likely that loneliness and isolation will play heavily into the arena of boredom and its associated degrading effects.

The prior comment concerning piecemeal problem-solving approaches also brings another critical issue to the fore. We have programs that seek to understand the influence of physical conditions such as confinement, lighting, habitability, radiation and the like, and we also have research directed to numerous psychological dimensions such as crew composition (Bell, Brown, Abben, & Outland, 2015), astronaut selection, training, and other associated health issues. These often feature assessment of these individual main effects. What such efforts often necessarily omit are the complex interactions that occur between such specific factors. For example, how does food quality affect mood, long-term health, and resilience? How do lighting conditions affect sleep and crew cohesion? More provocatively, how will mixed-gender crew composition affect overall mission outcome? Such questions mandate proxies, models, and simulations, even though we recognize that they necessarily fall short of the real situation (and see Hancock, 2009b; Hancock & Sheridan, 2011; Sawyer et al, 2012). This issue goes well beyond deep-space exploration alone. This issue reflects the emerging "systems" approach to understanding complex workplace performance and health concerns (and see Carayon et al, 2015). Since interactive effects proliferate so rapidly as we add differing sources of influence, which also vary across time, and since nominally predictive models must assume certain functional linkages between these impactful interactive elements, then without exhaustive empirical foundation, we necessarily often have to engage in a "learning by doing" strategy. While this tactic may disturb those who aspire to assess and regulate all putative risk, the actual injection of a degree of (requisite) variability into operational systems may not always necessarily be a bad thing either (and see Hollnagel, 2014). As the formal reduction of uncertainty, information is the foundation of human interest. Such uncertainty with its inherent challenges combats boredom. We must look to ensure that our missions provide micro-levels of meaningful challenge, alongside the manifest macro-challenge of the whole enterprise.

c. <u>Are We There Yet?</u>

On a long and tedious journey, how many of us have not heard the plaintive inquiry "are we there yet?" from the less than patient members of our family's crew? It is a legitimate question. In both the broad and narrow view of the Mars mission, the answer to this question is – not yet. While boredom is the specter raised here, perhaps this will not be such an issue on the first mission. After all, like the earliest Moon missions such as Apollo 8 and Apollo 11, the eyes of the world will be upon this crew. They will be news, and the first human to set foot on another planet is assured species-wide celebrity (assuming they return successfully) or glorious martyrdom (if they do not). No, boredom may well bide its time. In keeping with our movie theme, let us not forget the rather violent reaction of Sharon Stone's character in *Total Recall* (1990) as she kicks our hero, played by Arnold Schwarzenegger, with the comment: "That's for making me come to Mars!" or the comment in *Apollo 13* that even this third flight to the Moon has lost its sparkle and public interest.[8] For, after explorers come pioneers, those individuals who actually settle the new world.

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[8] This particular form of experience was perhaps first encountered in Gemini 7, the two-week mission of James Lovell and Frank Borman to test whether extended residence in space was harmful. They described their experience as being: "Like two weeks in a men's room." (McCoy, 1966), and with each noting that it was the longest two weeks of their lives. Of course, each was later a member of the highly successful Apollo 8 crew, and the conditions on that somewhat shorter mission improved the affective nature of the experience considerably.

It may well be that it will be on later missions that boredom really takes effect. After all, for each successive flight the pervasive impact of automation will exert an ever-greater effect. Human astronauts may encounter less in terms of active fatigue (i.e., engaging in rote but demanding tasks over and over again), than passive fatigue (doing nothing for extended periods of time), which is a primary precursor of boredom (Desmond & Hancock, 2001).

Meaningful patterns of information obviate boredom and can institute restorative effects (Emfield & Neider, 2014; Kaplan, 1995). However, if such stimulation is unavailable then one option is to "withdraw." In the long days of our terrestrial winter, may forms of life have sought survival through hibernation and there is evidence that reduced body temperature induces acceleration in the subjective sense of time (Hancock, 1993). Perhaps our solution to boredom lies in some physiological innovation in the form of the "cryo-sleep" that fiction continues to tout and science still fights to make progress on (Merkle, 1992). It may perhaps be the case that we will "bed-down" for deep-space journeys, telling our automation to just "wake us up when we get there." Right now, this vision is more fiction than fact. Of course, we could just shorten the journey, at least in temporal terms simply by going faster. As we reach beyond Mars, we will certainly have to find innovative and more effective forms of propulsion and the physics and engineering research surrounding such a challenge proceeds apace. Right now, however, such technologies are not available and current mission planning is predicated upon existing systems. So, we are not there yet in any sense. But we have begun our journey.

d. The Other Things

To the present juncture, we have considered a number of what might be recognized as known or "traditional" barriers to achieving a successful mission to Mars and here I have especially featured boredom. Yet there are numerous other interactive concerns which can readily be envisaged but which we do not yet have solutions. Technically, this latter group and their influence are composed of what Sheridan (2014) referred to as "known-unknowns." Let us then turn to one particularly polemic example of one such known-unknown effect. It is a strong probability that there will be a mixture of the sexes on the Mars mission. Indeed, our current social mores appear to demand it. Further, given the arduous and rigorous tests that will be used to screen this cadre of most exceptional members of humanity, these individuals are likely to be in the "prime" of their life. We are aware, and yet, sadly remain socially repressed concerning our response to any contextual sexual activity as is liable to occur. However, sex is a critical facet of, and a prime motivator in human existence. While some brave individuals (e.g., Gallagher, 2000; Woodmansee, 2006) have broached this important issue, and even space scientists have intrinsically acknowledged the problem[9], the puritanical nature of some elements of contemporary American society continues to mean that this remains either an investigational taboo or one that can only be discussed behind closed doors as though not fit or appropriate for wider social consideration. Indeed, it may be predicted that should this present work see wider publication, this will be the immediate issue upon which the more extensive media will focus, neglecting or ignoring all of the other concerns that

[9] See: http://www.dailymail.co.uk/sciencetech/article-1165837/Women-excluded-Mars-mission-crew-prevent-sexual-tension-ruining-105-day-voyage.html (accessed 8-25-17). See also: Saralyn, M., Scott, G.B.I, Donoviel, D.B., Leveton, L.B., Mahoney, E., Charles, J.B., & Siegel, B. (2013). The impact of sex and gender on adaptation to space. Technical Report, DECADAL Study papers.

have been raised. This situation is an asinine one. As part of the normal panoply of human behavior, we cannot simply neglect or ignore this dimension of social interaction. As Maslow's (1954) "hierarchy of human needs" has posited, both social and sexual intercourse are prime motivators of human behavior. Further, at the very least, both can well be considered anodynes to periods of extensive boredom and must therefore be heavily factored into the issue of chronic underload that we face in our efforts at deep-space exploration. This is all part of a greater subset of concerns for privacy and team cohesion, which are also each crucial to success.

Contingent upon the number of crew members and their specific composition and sexual orientation, considerable sexual tension may well be experienced across such a crew, for whom teamwork will be perhaps one of the most important markers of success (see Bell et al., 2015). And, of course, reaching the eventual pinnacle of crew selection will require a strong and ambitious drive in such individuals (cf., Wolfe, 1979). As such, we are liable to encounter above normal levels of sex drive in at least some of the selected individuals. Although such challenges are easily envisaged (e.g., *Red Planet*), they are not so easily addressed. Indeed, all forms of social activity necessarily interact with issues such as habitability, personal space, privacy, absolute pressurized volume, crew cohesion, etc. Also, the pure physics of such intercourse in a gravity-diminished environment are themselves not trivial. While not an easy issue we systematically, systemically, and socially ignore such concerns at our peril. If the Mars mission is truly an international endeavor, and this is very likely to be the case, we must add in the effects of culture and associated cultural expectations to this concern. If boredom threatens to be a silent killer, social dysfunctionality promises to be a spectacularly public one.

If the incipient beginning of life is an issue on the way to Mars, so is its ending. While we must necessarily countenance the risks of catastrophic overall mission failure, there is also a finite but non-trivial possibility that one or more members of the crew will be incapacitated or even expire on mission. This could happen at various stages of the overall voyage. If the person does not recover from a medical emergency, we are faced with the questions as to what do we do with the corpse? Burial on Mars itself is a possibility but if death occurs in transit, there are significant issues to be faced. What happens if that death is the result of murder? While *Murder on the Mission to Mars* is an alluring alliterative title, what of jurisdiction, indeed what of law itself under such circumstances (Szocik, Lysenko-Ryba, Banas, & Mazur, 2016)? The maritime solution may not be relevant and perhaps we will need a new branch of space law? In the same way that the capsule will have its own culture and time, it may well develop its own informal "rule of law." It is not only the communication issue that is raised by the remoteness of these operations but it is the central narrative of human sociological structure that may be challenged by this journey. Some will argue that these issues are remote and indeed far-fetched eventualities which must necessarily be relegated to secondary consideration. Others might observe that such events could act as palliatives for the behemoth of boredom that has been raised here. Such observations are perhaps correct. But if matters of life and death, the very pith of living, do arise, they may well become more destructive than any of the technical challenges upon which we focus so much of our time and resources, or even the specter of boredom that I have raised here.

e. <u>Crews are for Mars; Robots are for Venus</u>

The great engineering temptation is to "automate everything." This courts the deterministic seduction that lures us with the siren call of certainty. If only we can reduce the mission to a finite series of known steps and deal with each of them *seriatim* then we can address those pernicious problems of risk assessment and failure potential. Of course, at heart we know that this is not true but it has proved so effective in supporting our present state of progress that we inherently adhere to this strategy despite its evident flaws. One facet of the automation explosion (Hancock, 2014) is the ever-increasing use of robotic assets. This makes clear sense since robots have already been to Mars. But over-automation denudes and dilutes the essential human contribution. Already we are seeing in terrestrial circumstances that overtaking of human professions by varying and increasing degrees of automation. Frey and Osborne (2013) have looked to provide an assessment of the probability that a wide spectrum of terrestrial occupations will be overtaken and essentially extirpated by incipient automation. In this, it is not only rote tasks or those requiring a simple repetitive sequence of actions that prove to be vulnerable to automation and in peril of extinction (as far as human performers are concerned). Advanced software solutions are now penetrating ever-further into what we see as complex and sophisticated decision-making tasks and it is a salutary thought to consider the vulnerability of one's own profession to such incursions. While robots are at present largely confined to tasks that are "dirty, dumb, and dangerous," the thresholds of their operational range expand on a daily basis. But robots in particular, and automation in general, if conceived and enacted in a human-centered manner (see Hancock, 2017b), prove to be valuable teammates rather than insensate replacements. There are places where robots are naturally preferred for their operational capacities but there persist many and diverse circumstances where a human presence is essential. Robots will be there when we step on Mars but it will be the human presence that will make this a watershed event in the history of global civilization.

f. <u>The Insurance of Mars</u>

Our first voyage to another heavenly body was motivated by a complex interplay of social, political, military, and even spiritual aspirations and inspirations. It is equally as sure that our next step out into the wider solar system will be impelled by an equivalently complex nexus of causal factors. Yet failure necessarily haunts these faltering first steps at human planetary exploration and we must pre-reconcile ourselves to the reasonable expectation that we will suffer loss and even complete and catastrophic failure amongst our first such attempts. Indeed, this has historically been the pattern we have previously experienced in our exploration of the inhospitable regions of our own planet (e.g., Cherry-Garrard, 1922). Any such failure will be no reason to cease our efforts. Those brave individuals who embrace such challenges and their associated dangers will deserve the legacy of follow-up efforts which build upon their achievements, be those achievements either "objective" failure or manifest success. Some of the major behavioral barriers that we have to overcome certainly include harmonious crew-composition, crew-cohesion, and thus the central importance of crew selection and training. Boredom lies behind a number of these critical dimensions and we must acknowledge now that boredom is rather unlikely to be identified in any forensic investigation of failure. Given varying human levels of tolerance for boredom, what will be the precise composition of such a crew? Will the "crew" be composed of only those individuals in the vehicle? Or will it include the human members on ground-ops also? Surely, we must also envisage that automation will represent a viable and even dominant contributor and ever-greater influence on any elaborated crew, as Clarke's *2001: A Space Odyssey* (1968) foretold. Neither can we neglect embodied robots that will also represent necessary physical elements in any Mars-based exploration team. After all, in real terms such entities have been there before. Just who the "crew" are need not be a small finite set of individuals, but perhaps is better conceived as a complex and elaborated sociotechnical system. Such a perspective, in and of itself, might prove to be a potential game changer.

Like the mechanization of war, the mechanization of space extracts much of the inherent human interest from the enterprise. Humans only voluntarily pay for what they are interested in. Otherwise governments must impose an associated and mandatory levy in the form of obligatory taxation. However, our public budget for space is largely a discretionary resource, although one can make a clear argument that, like defense, it should be obligatory. The human astronaut may well be vulnerable to many systemic threats and requires much in terms of aid and resources to survive and prosper. Like the need to secure the supportive backing and interest of the species on Earth, we need to pay crucial attention to the interest of those on board. Thus, at one and the same time, boredom threatens both the crew and the social support structure for the very program which transports them (Hancock, 2015). In short, if such long-duration missions "bore" the public, they are unlikely to support them. While it may not be much fun, failure to pay attention to boredom threatens to kill on more levels than one.

However, in the end, we also have to ask ourselves what is the cost of *not* going to Mars? In some ways Mars represents our species' backup survival plan. If the viability of Earth as a supportive biosphere is threatened, either by external or internal sources of destruction, then Mars may well be the only physical recourse for human beings. There are many 'quasi-calculational' ways to try to quantify the value of such backup insurance. But regardless of the relative accuracy of these fiduciary estimates, it is more than possible to make a convincing qualitative case for much greater levels of public support for the enterprise of Mars. Thus, whatever the attractions of inter-planetary exploration, we must also acknowledge that the finite and arguably growing possibility of terrestrial Armageddon must also impel us towards the red planet. On the brighter side, our experience tends to show us that such efforts are liable to render considerable and significant financial return, in and of themselves. In our present times, it is the vista of profit that will perhaps prove most persuasive. In short, Earth 2.0 equals Mars.

III. Summary and Conclusions

Mars stands squarely in the crosshairs of human evolution. It is our next natural stepping stone out into greater reaches of space. Humans have already generated wonderful technical achievements in placing our robotic representatives on its surface. These orthotic extensions of our own capacities provide us with significant amounts of new and vital information. Yet robotic exploration will never be enough. The very basis of our ubiquitous human narrative requires us to identify with, and empathize with, a human hero (Campbell, 1949). Mars will only be "conquered" when the first human sets a foot upon it. The obvious challenges involved with this journey currently coalesce around the technical barriers to physical transportation from our planet to the red planet, and back again. Included in such a mindset are all of the systems of transport, propulsion, and life-support that sustain the continuance of the astronaut's very existence. In a manner analogous to Maslow's (1943) hierarchy, we conceive of such supports as an a priori necessity upon which any subsequent actions or states must necessarily be erected, one upon the other. However, this ordering may not be exactly correct. The quintessential heart of a human mission to Mars is to place a fully functional human being on its surface. For such purposes, physiological health must act to support psychological well-being. Psychological well-being demands a fully alert, fully responsive individual and not one who is chronically challenged from the hidden stress of extensive boredom. Hidden affective killers will prove all the more effective as a result of being overlooked or relegated to subsidiary concerns as the more manifest technical challenges assume what is thought to be a "natural" priority. Therefore, the present work suggests that, in its essence, conquering the red planet must feature the centrality of astronauts' competent cognitive capacities. It will be through *the eyes and the brain* of these brave pioneers that we will embrace a fully empathic experience. Yet such individuals have to be *compos mentis* to communicate the wonder and awe that society will demand of them. Underload, fatigue, and ennui are all anathema to this cognitive well-being, and indeed, transcendence. Boredom is a silent and patient killer and it is one we must completely defeat if the Olympus of Mars is to be ours.

References

Barmack, J.E. (1937). Boredom and other factors in the physiology of mental effort: An exploratory study. *Archives of Psychology*, *218*, 1-83.

Bell, S.T., Brown, S.G., Abben, D.R., & Outland, N.B. (2015). Team composition issues for future space exploration: A review and directions for future research. *Aerospace Medicine and Human Performance*, *86* (6) 548-556.

Caldwell, J.A., & J.L. Caldwell. (2003). *Fatigue in aviation*. Farnham, Surrey, England: Ashgate.

Campbell, J. (1949). *The hero with a thousand faces.* New York: Pantheon.

Cherry-Garrard, A. (1922). *The worst journey in the world: A tale of loss and courage in Antarctica*. London: Constable.

Clark, A. (1998). *Being there: Putting brain, body, and world together again*. Boston: Bradford Books, MIT Press.

Clark, B., & Graybiel, A. (1957). The "break-off" phenomenon. *Journal of Aviation Medicine*, *28*, 121-126.

Coker, C. (2009). *War in an age of risk*. Cambridge, England: Polity Press.

Davies, D.R., Shackleton, V.J., & Parasuraman, R. (1983). Monotony and boredom. In: G.R.J. Hockey (Ed.). *Stress and fatigue in human performance*. (pp. 1-32). New York: Wiley.

Dekker, S.W.A., Hancock, P.A., & Wilkin, P. (2013). Ergonomics and the humanities: Ethically engineering sustainable systems. *Ergonomics*, *56* (3), 357-364.

Desmond, P.A., & Hancock, P.A. (2001). Active and passive states of fatigue. In: P.A. Hancock and P.A. Desmond (Eds.). *Stress, workload, and fatigue*. (pp. 455-465). Mahwah, New Jersey: Lawrence Erlbaum.

Emfield, A.G., & Neider, M.B. (2014). Evaluating visual and auditory contributions to the cognitive restoration effect. *Frontiers in Psychology*, *5*, 548.

Frey, C.B., & Osborne, M.A. (2013). *The future of employment: How susceptible are jobs to computerisation.* Oxford Martin School. Oxford, England: University of Oxford Press.

Gallagher B. (2000). No space sex? *Scientific American*, *282*, 22.

Hancock, P.A. (1980). Sensory deprivation in long distance swimming: A psychological stress factor? *Swimming Technique*, *16*, 122-123.

Hancock, P.A. (1982). Task categorization and the limits of human performance in extreme heat. *Aviation, Space, and Environmental Medicine*, *53*, 778-784.

Hancock, P.A. (1993). Body temperature influences on time perception. *Journal of General Psychology*, *120* (3), 197-216.

Hancock. P.A. (2009a). *Mind, machine and morality*. Chichester, England: Ashgate.

Hancock, P.A. (2009b). The future of simulation. In: D. Vincenzi, J. Wise, M. Mouloua, and P.A. Hancock (Eds.). *Human factors in simulation and training*. (pp. 169-186), Boca Raton, FL: CRC Press, Taylor & Francis.

Hancock, P.A. (2014). Automation: How much is too much? *Ergonomics*, *57* (3), 449-454.

Hancock, P.A. (2015). The royal road to time: How understanding of the evolution of time in the brain addresses memory, dreaming, flow and other psychological phenomena. *American Journal of Psychology*, *128* (1), 1-14.

Hancock, P.A. (2016). The bleeding of conscious intensity *Journal of Neurology and Neuro-Rehabilitation Research*, *1* (2), 13-14

Hancock, P.A. (2017a). *Transports of delight*. Springer: Cham, Switzerland.

Hancock, P.A. (2017b). Imposing limits on autonomous systems. *Ergonomics*, *60* (2), 284-291.

Hancock, P.A., & Carson, D.M. (1986). The time trap: Temporal incongruences under stressful conditions. *Aviation, Space, and Environmental Medicine*, *57* (12), 1217.

Hancock P.A., & Drury, C.G. (2011). Does human factors/ergonomics contribute to the quality of life? *Theoretical Issues in Ergonomic Science, 12*, 1-11.

Hancock, P.A., Hancock, G.M., & Warm, J.S. (2009). Individuation: The N=1 revolution. *Theoretical Issues in Ergonomic Science*, *10* (5), 481-488.

Hancock, P.A., & Krueger, G.P. (2010). Hours of boredom – moments of terror: Temporal desynchrony in military and security force operations. Center for Technology and National Security Policy: Defense and Technology Paper, Washington, DC.

Hancock, P.A., & Sawyer, B.D. (2015). Judging thieves of attention. *Human Factors*, *57* (8), 1339-1342.

Hancock, P.A., & Sheridan T.B. (2011). The future of driving simulation. In: D.L. Fisher, M. Rizzo, J.K. Caird., and J.D. Lee, (Eds.). *Handbook of driving simulation for engineering, medicine and psychology*. (pp. 4:1-11), Boca Raton, FL: CRC Press.

Hancock, P.A., & Warm, J.S. (1989). A dynamic model of stress and sustained attention. *Human Factors*, *31*, 519-537.

Hartig, T., Mang, M., & Evans, G.W. (1991). Restorative effects of natural environment experiences. *Environment and Behavior*, *23* (1), 3-26.

Hill, A.B. (1975). Work variety and individual differences in occupational boredom. *Journal of Applied Psychology*, *60*, 128-131.

Hollnagel, E (2014). *Safety-I and Safety-II: The past and future of safety management*. Chichester, England: Ashgate.

Hubbard, S. (2011). *Exploring Mars*. Tucson, AZ: University of Arizona Press.

Kanas, N. (2011). From Earth's orbit to the outer planets and beyond: Psychological issues in space. *Acta Astronautica*, 68(5), 576-581.

Kanas, N. (2015). *Humans in space: The psychological hurdles*. Springer: Cham, Switzerland.

Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, *15*, 169-182.

Lazarus, R.S., & Folkman, S. (1984). *Stress, appraisal and coping*. New York: Springer.

Lovelock, J. (1979) *Gaia: A new look at life on Earth* (3rd ed.). Oxford, England: Oxford University Press.

Marras, W., & Hancock, P.A. (2013). Putting mind and body back together: A human-systems approach to the integration of the physical and cognitive dimensions of task design and operations. *Applied Ergonomics*, *45* (1), 55-60.

Magnuson, S. (2015). Power remains key challenge for building SOCOM's iron man suit. *National Defense*, *94*, 38-42.

Maslow, A.H. (1943). A theory of human motivations. *Psychological Review*, *50* (4). 370-396.

Maslow, A.H. (1954). The instinctoid nature of basic needs. *Journal of Personality*, *22* (3), 326-347.

Matthews, G., Desmond, P.A., Neubauer, C., & Hancock, P.A. (Eds.), (2012). *The handbook of operator fatigue*. Farnham, Surrey, England: Ashgate.

McCoy, M. H. (1966, February 21). "Like two weeks in a men's room." *Milwaukee Sentinel*, pp. 1A, 12A.

Merkle, R.C. (1992). The technical feasibility of cryonics. *Medical Hypotheses*, *39* (1), 6-16.

Parasuraman, R., & Manzey, D.H. (2010). Complacency and bias in human use of automation: An attentional integration. *Human Factors*, *52* (3). 381-410.

Pirolli, P.L.T. (2009). *Information foraging theory: Adaptive interaction with information*. Oxford, England: Oxford University Press.

Pirolli, P.L.T., & Card, S.K. (1999). Information foraging. *Psychological Review*, *106*, 643-675.

Reinerman-Jones, L., Sollins, B., Gallagher, S., & Janz, B. (2013). Neurophenomenology: An integrated approach to exploring awe and wonder. *South African Journal of Philosophy, 32 (4), 295-309.*

Roach, M. (2016). *Grunt: The curious science of humans at war*. New York: W.W. Norton.

Sawyer, B.D., Hancock, P.A., Deaton, J., & Suedfeld, P. (2012). Finding the team for Mars: A psychological and human factors analysis of a Mars Desert Research Station crew. *Work: Journal of Prevention, Assessment, and Rehabilitation*, *41*, 5481-5484.

Schaefer, K.E., Adams, J.K., Cook, J.G., Bardwell-Owens, A., & Hancock, P.A. (2015). The future of robotic design: Trends from the history of media representations. *Ergonomics in Design*, *23* (1), 13-19.

Sheridan, T.B. (2014). *What is God? Can religion be modeled?* Washington, DC: New Academia Publishing.

Smith, R.P. (1981). Boredom: A review. *Human Factors*, *23*, 329-340.

Sours, J.A. (1965). The "break-off" phenomenon: A precipitant of anxiety in jet aviators. *Archives of General Psychiatry*, *13* (5), 447-456.

Stevens, S.S. (1973). *Edwin Garrigues Boring 1886-1968*. Washington, DC: National Academy of Sciences.

Suedfeld, P. (1975). The benefits of boredom: Sensory deprivation reconsidered. *American Scientist*, *63*, 60-69.

Szocik, K., Lysenko-Ryba, K., Banas, S., & Mazur, S. (2016). Political and legal challenges in a Mars colony. *Space Policy*, forthcoming.

Thackray, R.I. (1981). The stress of boredom and monotony: A consideration of the evidence. *Psychosomatic Medicine*, *43*, 165-176.

Thompson, L.A. (1929). Measuring susceptibility to monotony. *Personnel Journal*, *8*, 172-197.

Wall Street Journal (2014, July 4). U.S. Army's “Iron Man” suit coming soon.

Wolfe, T. (1979). *The right stuff*. New York: Farrar, Straus & Giroux.

Woodmansee, L. (2006). *Sex in space*. Ontario, Canada: CG Publishing Inc.

Zubek, J.P. (1969). (Ed.). *Sensory deprivation: Fifteen years of research*. New York: Appleton, Century, Crofts.

Zubek, J.P. (1973). Behavioral and physiological effects of prolonged sensory and perceptual deprivation: A review. In: J. Rasmussen, (Ed.). *Man in isolation and confinement*. (pp. 9). Herndon, VA.: Transaction Publishers.

The Space Age Narrative as Reflected in Southern Music

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ABSTRACT - This article briefly explores the notion of the Space Age as a historical and cultural construct in the Southeastern United States through an analysis of Southern music across a range of time periods and genres. It argues that the Southern culture reflects a complex understanding of the space age as a technological and political phenomenon with both global and local impacts.

I. Introduction

The Space Age as a construct presents an interesting network of technical, political, and cultural markers that help to define the shift in perception that humankind underwent as it began to perceive itself in the context of space travel. The ability to look back at the Earth and visualize the planet as a global space represented a dramatic shift in the cultural and political imagination of peoples worldwide. At the same time though, the world was being constructed around divisions between two dominant super powers with fault-lines running along oppositional political ideologies. This created a number of narratives within dominant culture that framed the space age and the Space Race in terms of the wonder of scientific achievement coupled with the existential threat of the others technology. Space was more than just a novelty; it transformed the public's imagination of what was possible, but did so in terms on international competition.

These narratives were in turn shaped by a new ability to conceptualize "humankind" as a definite group, a group in which there was no "other."[1] Space exploration initially developed within an emerging international governance system that evolved in the wake of World War II and the Holocaust. This new system gave the individual human being a status in global society for the first time through the concept of human rights. The U.N. Charter[2] and the Universal Declaration of Human Rights[3] were both formative texts that reshaped international governance along the lines

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[1] This theme can readily be seen in the emergence of law governing outer space, which sought to govern space activities for the "common interest of mankind." U.N. General Assembly Res. 1348 (XIII). *Question on the peaceful uses of outer space* (Dec. 13, 1958), http://www.unoosa.org/pdf/gares/ARES_13_1348E.pdf.

[2] *See* U.N. Charter, Art. 1(2).

[3] U.N. General Assembly Res. 217 A(III). *Universal Declaration of Human Rights* (Dec. 10, 1948).

of improving conditions for humankind as a whole. The Space Age helped to entrench this restructuring by literally imaging the world as global space and allowing for shifting conceptualizations of both geography and humankind.[4] Of course, inequality was not immediately or completely obliterated, but these frameworks gave minority populations footholds from which to assert their rights by framing their complaints within dominant narratives.

The American South was no different. Marked by both racial and economic inequalities, the minority groups were struggling to obtain social and political rights within the context of the American Constitution. This claim was given footing by the emerging notion of "humankind" at the international level. This meant that these groups both co-opted dominant narratives to link their claims to reflect dominant cultures and produced counter-narratives that critiqued the structure of the system. This article will illustrate this co-option and production in the context of southern music traditions, and argue that this helps to create a rich place for space within the folk life of the southern United States. Further, by focusing on localized reactions to global processes, this article will seek to show how technological advances helped to embed international politics and international processes into local narratives.

This first section of this article will address why this research focuses on the American South as a context for understanding how space narratives were produced in local cultures. Second, this article will address briefly the effect of the Space Age on the broader political and cultural imagination and explore the construction of the Space Age in terms of politics and society. The third section will trace space narratives found within the southern musical traditions. Finally, this article will conclude with reflections on what these narratives mean in terms of both constructing southern culture and in terms of technological change, and it will argue that the existence of such themes challenges romantic notions of the "primitivity" of southern music.

II. Southern Space

The American South at first glance may seem like an unlikely focal point for an investigation of space themes on local culture. Predominantly rural and poor, the American South seems to be a poor setting for examining Space Age narratives. However, the South presents a unique place in which to observe these narratives.

First, the American South presents a unique setting in which American music developed. Traditions such as bluegrass,[5] blues,[6] and jazz[7] all emerged from different locals in the South. These traditions in turn were highly influential in shaping modern rock, country, and R&B genres.[8] The area has been a focal point for researchers and is considered central to American roots music.

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[4] The first image of Earth from space was captured by a camera on a V-2 missile in 1946. Jason Major, "This Is the Very First Photo of Earth from Space," *Universe Today*, October 24, 2014, http://www.universetoday.com/115641/this-is-the-very-first-photo-of-earth-from-space/.

[5] *See generally* Cecelia Tichi, *High Lonesome: The American Culture of Country Music* (Chapel Hill: UNC Press 1994).

[6] *See generally* Alan Lomax, *The Land Where the Blues Began* (New Press 2002).

[7] *See generally* Frank Tirro, *Jazz: A History* (New York: W.W. Norton 1977).

[8] So, for instance Guralnick traces such influences on the rock music of Elvis Presley. *See generally,* Peter Guralnick, *The Last Train to Memphis: The Rise of Elvis Presley* (London: Abacus 1999).

As a result of this rich tradition, the music of the South gives a unique glimpse at the folk life and processes of the region.

Second, space loomed large in the region. The south is home to several NASA centers: Johnson Space Center in Texas, Michoud Assembly Facility in Louisiana; Stennis Space Center in Mississippi; Marshall Spaceflight Center in Alabama; Kennedy Spaceflight Center in Florida; Langley Research Center in Virginia; and Wallops Flight Facility in Virginia.[9] In addition to these several private spaceports are located or currently being planned in the region.[10] Indeed the South's extensive coastline and low population density makes it an excellent choice for safely engaging in highly risky space activities. The South became a setting for space activities as the United States and, as such, a site for the development of technologies central in geopolitical tensions of the time.

Finally, the south was central in American political processes during the height of the space race. Powerful southern senators such as Lyndon B. Johnson and John C. Stennis helped to shape American space exploration (as can be seen by the NASA centers bearing their names. The South was also a central point for the Civil Rights Movement, which means that the space race with its global overtures was framed in terms of local inequalities within the space of the South. Galloway notes that Sen. Johnson, the chief architect of the 1958 National Aeronautics and Space Act, was at the same time working on a number of rights issues.[11] The juxtaposition of high technology against rural poverty is complex. It both opened doors for integration[12] and displayed the vast inequalities that remained in the region.[13] This means that the narratives revealed through the musical tapestry of the South reflect distinct awareness of the complex political arrangements being shaped by and shaped around the Space Race.

III. <u>Constructing the Space Age</u>

This section will discuss how the Space Age was constructed as a broad cultural narrative with specific emphasis on the American context. It will argue that while the space age furthered political claims of a universalistic view of "humankind" as a social group, the American construction adopts classic philosophical fault-lines that reflect a world deeply divided. These fault-lines are then mirrored in in the construction of the Space Age in the American South.

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[9] NASA, "NASA Centers and Facilities," https://www.nasa.gov/about/sites/index.html (accessed June 12, 2015)

[10] These include the Mid-Atlantic Regional Spaceport in Virginia (http://www.marsspaceport.com/); Midland Air and Space Port in Texas (http://www.flymaf.com/35/Spaceport); Oklahoma Spaceport (http://airspaceportok.com/); Cecil Field in Florida (http://www.flyjacksonville.com/content.aspx?id=406); Alabama Spaceport (*see* Jason Koebler, "Alabama Wants to Build a Spaceport," *Motherboard* (June 3, 2015) http://motherboard.vice.com/read/alabama-wants-to-build-a-spaceport); and Camden County in Georgia (*see* "Camden County Spaceport," *The Georgia Space Society* (Feb. 4, 2014) http://spacegeorgia.org/2014/02/04/camden-county-spaceport-update/).

[11] John M. Logsdon, ed., *Legislative Origins of the National Aeronautics and Space Act of 1958: Proceedings of an Oral History Workshop: Conducted April 3, 1992* (Washington, D.C.: Government Printing Office, 1998) at 57-58.

[12] Steve Inskeep, "How NASA's Space Race Helped to Integrate the South," *NPR* (May 6, 2015), http://www.npr.org/2015/05/06/404626521/we-could-not-fail-the-first-african-americans-in-the-space-program.

[13] For example, Nelson poses the question of how an industrialized society that can place humans on the moon cannot address the problem of urban ghettos. *See* Richard N. Nelson, *The Moon and the Ghetto: An Essay in Public Policy Analysis* (Norton 1977) and Richard N. Nelson, "*The Moon and the Ghetto* Revisited," *Science and Public Policy*, v. 38/2 (2011) 681-690.

The project of developing a concept of "humankind" has been an ongoing one in political philosophy with deep roots in Kantian literature.[14] After the horrors of the Holocaust, the international community reorganized itself and began an ongoing process of incorporating the individual as a legal subject that received some basic set of rights based solely on the fact that that individual was human.[15] The 1945 UN Charter clearly notes that "promoting and encouraging respect for human rights and for fundamental freedoms for all without distinction as to race, sex, language, or religion."[16] This was followed by the Universal Declaration of Human Rights in 1948.[17] Both of these documents express the notion of a universal human group that had core rights enforceable against the state.

The legal imagination for conceptualizing humankind was reinforced by a growing cultural notion of a global social group. Outrage over the Holocaust had allowed for the idea governments were limited in the exercise of their power within their territorialized borders. This was complimented by rapidly expanding communications and transportation systems, which allowed cosmopolitan ideologies to thrive. The Space Age contributed to this notion as well. *Sputnik I* did more than simply ignite a technological battle between the United States and the USSR, it changed the social imagination overnight. It opened up the world simply by overflying other countries[18] and it "shocked the American political system into action."[19] For the first time, an individual was able to envision the world as a global space in a quite literal sense. The first photo of Earth from an orbiting satellite was taken by *Explorer VI* in 1959[20] and the famous Blue Marble shot, which was the first photo of the full Earth from space, was taken in 1972.[21] Coupled with this visual consciousness, it was the use of space for transnational communications allowed for easy contact with individuals in other countries.[22] In short, the technology of the Space Age, rescaled and respatialized the common geography of the Earth.

While the space age was helping to create constructs for re-conceptualizing the other, it was doing so in a world that was divided by the Cold War. This, of course, is critical to understanding how space age narratives are built. Because the Cold War cleaved along ideological lines, the other is politically constructed. Both the US and the USSR made claims to be the best political

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[14] See generally, Immanuel Kant, *Perpetual Peace: A Philosophical Sketch* (1795) available at: www.constitution.org/kant/perpeace.htm.

[15] Interestingly, theories on how one treats the otherworldly nonhuman were developing at the same time. This line of thinking was pioneered by Andrew G. Haley, see generally, Andrew G. Haley, "Space Law and Metalaw-Jurisdiction Defined." *J. Air L. & Com.* 24 (1957): 286.

[16] U.N. Charter, Art. 1(3) (1945).

[17] Universal Declaration of Human Rights, U.N.G.A. Res. 217 A (III) (Dec. 10, 1948).

[18] Walter McDougall, *The Heavens and the Earth: A Political History of the Space Age* (New York: Basic Books, 1985) 141-156.

[19] John M. Logsdon, ed., *Legislative Origins of the National Aeronautics and Space Act of 1958: Proceedings of an Oral History Workshop: Conducted April 3, 1992* (Washington, D.C.: Government Printing Office, 1998) at vii.

[20] NASA, "First Picture from Explorer VI Satellite," NASA Image 59-EX-16A-VI (Aug. 14, 1959) available at: https://www.flickr.com/photos/nasacommons.

[21] NASA, "History of the Blue Marble," available at: http://earthobservatory.nasa.gov/Features/BlueMarble/BlueMarble_history.php.

[22] Arthur C. Clarke had predicted this early on in his "Extra-Terrestrial Relays: Can Rocket Stations Give World-wide Radio Coverage?" *Wireless World*, October 1945, 305-308, available at: http://lakdiva.org/clarke/1945ww/1945ww_oct_305-308.html. The first direct relay telecommunications satellite was *Telstar I* and was launched on July 10, 1962. McDougall, *supra* note 7, 358.

system for providing basic human rights, and as a result, the Space Race was built on the competition of two opposed political systems attempting to achieve the project of building humankind through opposing mechanisms. Otherness becomes a political problem as opposed to a problem of immutable qualities. This led to intensive competition in technological fields, which meant that the social imagination embedded concepts of technological prowess into nationalistic sentiments. Technology in this sense is the result of the political process. The social imagination was able to encompass both the universality of humanness as well as construct an "other" that needed liberation yet was also to be viewed with skepticism. This is reflected in the duality of the national pride felt by the United States with the Moon landing as a triumph over the Soviet Union, and the rhetoric deployed with the landing that emphasized that the landing was done on behalf of "all mankind."[23]

Such constructions were mirrored within southern socio-cultural relations as well. The south was plagued by poverty, which was aggravated by the increasing automation of the agricultural industry, and racial inequality became a centerpiece of the South's political landscape due to an increasingly vocal civil rights movement. At the same time that these issues were emerging, the South became a stronghold of critical infrastructure for the space program. The South boasts numerous NASA facilities, which placed ideas of space exploration and its accompanying technologies directly into the geographic, sociological, and cultural spheres of the South. This also brought the narratives of the Space Age into the socio-political contestations of southern society. For instance, the narratives of humankind at the international level helped to give credit to claims for social equality being made by African-Americans. It also made a stark example of economic inequality as impoverished southerners saw first-hand the extent of government spending during the Apollo missions.[24] At the same time though that it echoed inequalities, the Space Age was also contributing to the wonder space exploration as a narrative within southern culture that emphasizes technological and scientific inquiry.

IV. <u>Space in Southern Music</u>[25]

In recent years music scholarship has increasingly shed light on the fact that traditional music in the U.S. South is something more than a quirky and ingenious holdover of the region's rapidly disappearing agrarian identity. In the past three or so decades, a number of critics have brought to the table several key issues which work to deconstruct problematic notions of cultural authenticity and isolation, and encourage us to examine industry, multicultural interchange, the development and marketing of genres, and other forces of modern life as immovable realities in the formation and evolution of southern music. In his 2008 book *Linthead Stomp*, historian Patrick

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[23] NASA, "Apollo 11 Plaque Left on the Moon," available at: http://www.nasa.gov/centers/marshall/moonmars/apollo40/apollo11_plaque.html. The rhetoric is also found in Neil Armstrong's words during the Moon landing of "one small step for man; one giant leap for mankind." Ned Potter, "Neil Armstrong: How 'One Small Step' Became First Words on Moon," ABCNews.com, Jan 2. 2013, https://www.abcnews.go.com/Technology/neil-armstrong-small-step-words-moon-apollo-11/story?id=18115402.
[24] Roger D. Launius, NASA: A History of the U.S. Civil Space Program (Malabar, FL: Krieger Publishing Company) 185. See also, Guido van Rijn, *The Truman & Eisenhower Blues: African-American Blues and Gospel Songs, 1945-1960* (London: Continuum, 2004) 102-128.
[25] In order to make this article more listenable, the citations go to You Tube videos of the songs being cited to. While these citations are functionally informal, the authors find them more useful that citations to obscure records. We also find it to be more fun.

Huber decries the common assumption that the earliest recorded country music was pure, untouched resounding from the Anglo-American peasantry of Appalachian mountain hollows.[26] Huber explains that although the northern based commercial record companies of the 1920s certainly advertised the fiddling and banjo picking artists on their rosters as "hillbilly" folksingers, many of these early country music pioneers – Charlie Poole, Fiddlin' John Carson, Darby & Tarlton, The Dixon Brothers – were actually lowland southerners from sizeable, bustling textile mill cities of the piedmont regions of Georgia, Tennessee and the Carolinas.[27] In a related vein of study, music historian Elijah Wald works to demystify the exceedingly obscured and romanticized life and music of Mississippi blues musician Robert Johnson. Wald points out that although spellbinding and powerful, Johnson's recorded repertoire of thirty-one songs reflects as much of popular trends and commercial influences as it does any singular preoccupation with crossroads mythology or retentions of West African folk custom in the hoodoo underworld.[28] This is to say that Robert Johnson's creativity, as is the case with all outpouring of southern musical expression in the 20th century, cannot be wholly extrapolated or disentangled from contemporaneous narratives of American popular culture and transition.

How then, might southern musicians have asserted their feelings toward the colossal advances taking place on the international stage during the onset of space exploration? As in the case of many events and circumstances throughout American history, they turned no blind eye. Of course, "outer space" as a concept was no new topic to southern song. For generations balladeers and street criers had sung of man's relation to the celestial bodies above. This tendency took a particularly romantic turn in the Victorian era when sentimental parlor songs became all the rage and much of this repertoire gained footing in the oral tradition. The growth of industrialization served as a source of widespread anxiety and wonderment. Novelty songs like "Come Take a Trip in My Airship," (1904) a version of which was recorded in 1929 by the aforementioned North Carolina banjo player Charlie Poole, were immensely popular and spoke to growing public fascination with the miracle of human flight.[29] At the same time, various songs and ballads warned of the harmful and potentially catastrophic risks of technological advancement. Two of the most popular ballads in the American folk music canon, "John Henry" and "The Titanic," make use of real life events to illustrate the downfall of excessive industrializing and its harms to humanity. In the case of "John Henry," the African American railroad worker whose job is being replaced by the steam-powered drill, becomes a hero when he races the machine in a spike driving contest and somehow, miraculously, manages to beat it.[30] However, this heroic triumph comes at a great cost: John Henry loses his life and therefore becomes a symbol of the sacrifice of man's sacrifice to progress. In "The Titanic," the narrative takes a decidedly moralistic and prophetic tone as the excesses of man's curiosity and material desires lead directly to his downfall. And again, the narrator refers to the assumed disposability of working class people, as in South Carolina songster

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[26] Patrick Huber, *Linthead Stomp: The Creation of Country Music in the Piedmont South* (U.N.C. Press 2008).
[27] *Id.*
[28] Elijah Wald, *Escaping the Delta: Robert Johnson and the Invention of the Blues* (Amistad 2004).
[29] Charlie Poole, "Come Take a Trip in My Airship" available at: https://www.youtube.com/watch?v= u1hWLcMO7kw (accessed June 12, 2015). [Video is no longer available].
[30] We now know that John Henry was a real person from Holly Springs MS and that this event really took place at the Big Oak Tunnel near Coosa, Alabama. See Garst, John. "Chasing John Henry in Alabama and Mississippi: A Personal Memoir of Work in Progress," *Tributaries: Journal of the Alabama Folklife Association* 5 (2002): 92-129. For more on the John Henry legend and the music surrounding it see "The Legend of John Henry," http://www.ibiblio.org/john_henry/ (accessed June 12, 2015).

Pink Anderson's version, which makes the tragic yet brutally honest statement: "They put the poor below / They were the first that had to go. Wasn't it sad when that great ship went down?"[31]

It is no wonder that as the United States became engaged in World War II and the unfolding events of international conflict and turmoil quickly turned colossal in scope, southern musicians and singers would incorporate many of these events and topics into their songs, and this would result in a steady release of blues and folk material on the subjects of Roosevelt, Hitler, Mussolini, Pearl Harbor, and the atom bomb throughout the mid to late 1940s.[32] The Buchanan Brothers, a gospel country duo from rural Dade County, Georgia, would record a single in 1946 called "Atomic Power," a song which applauds the bombing of Nagasaki and Hiroshima and points to the invention of the atom bomb as being "given by the mighty hand of God."[33] The recording earned the Buchanan Brothers a spot on that year's country top ten list, and on the heels of that success they released another single (RCA Victor, 1947) which too carried Biblical resonances, although with more lighthearted and whimsical content, "When You See Those Flying Saucers."[34] Both of these tracks highlight a skepticism of high technology rooted in religious beliefs, but they also illustrate an awareness of growing technological innovation.

In the 1950s, as the American public grew increasingly aware of and enamored with the palpability of the notion of space travel and exploration, scores of musicians from various regions of the country were also drawn to this alluring topic and released their own musical interpretations and reactions to the controversy. They ranged from whimsical instrumental numbers and novelty dance pieces to overtly political ballads to silly story songs about sexual encounters with Martian and everything in between. So, for example, Nat King Cole's version of "Destination Moon" which expresses a vision of the future in which space travel is routinized:

There once was a time when the colorful thing to do

Was to call for a date on a bicycle built for two

But cars and trains and even planes all have had their day

Now the time is due to call for you in the modern atomic way.[35]

This musical phenomenon was given a name, with the Soviet Union's launching of the *Sputnik I* satellite, and this enormously significant event took place just as southern performers like Elvis Presley, Fats Domino, and Jerry Lee Lewis were shattering musical molds, transgressing social confines, and revolutionizing the American cultural landscape. In general, the majority of

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[31] For a collection of Titanic songs and lyrics see "Tragedies and Disasters," *The Folk Archive*, http://www.fol-karchive.de/tragic.html (accessed June 12, 2015).
[32] *See generally, Atomic Platters*, http://www.atomicplatters.com/index.php (accessed June 12, 2015)
[33] Buchanan Brothers, "Atomic Power," available at: https://www.youtube.com/watch?v=G4aRgvXxp3I (accessed June 12, 2015).
[34] Buchanan Brothers, "When You See those Flying Saucers," available at: https://www.youtube.com/watch?v=yrIcZjIvQM0 (accessed June 12, 2015).
[35] Nat King Cole, "Destination Moon," https://www.youtube.com/watch?v=7H5-oEP0iFk (accessed June 12, 2015). The lyrics were written by New York born Roy Alfred, but Cole was from Montgomery, AL. "Destination Moon also plays on the theme of sexualized technology. Another notable version is by Tuscaloosa, AL's Dinah Shore. Dinah Shore, "Destination Moon," https://www.youtube.com/watch?v=0pkiSPoZiIU.

the rock n' rollers of the late 50s and early 60s incorporated *Sputnik* and other advances in outer space exploration as a new and exotic creative platform for the expression of familiar teenage themes: fear, frustration, excitement, speed, and sexual desires. Billy Lee Riley, the Arkansas rockabilly singer who's Sun Records hit "Red Hot" was a hit in 1957, recorded a lesser known number that same year which demonstrates some of this fascination: "Flying Saucer Rock n' Roll."[36] And likewise, Carl Mann, a rockabilly singer from Huntingdon, Tennessee, released this dance piece the following year, "Satellite No. 2," which notably emulates *Sputnik I*'s beep in the opening guitar riff.[37] Indeed, there are many more rockabilly songs about *Sputnik*, and it seems as if you were not really a rockabilly band unless you had a *Sputnik* or a "satellite" song of some kind in the late 50s / early 60s.[38]

Blues musicians also took to writing about the subject, as can be heard here from Arkansas born blues piano player Roosevelt Sykes, who recorded this blues in 1958 for the Imperial label in New Orleans. "Sputnik Baby" demonstrates more of the sexual innuendo associated with rocket imagery in the era.[39] This is also rooted in the tradition of singing about automobiles as sexual power (for instance 'Terraplane Blues' by Robert Johnson[40]). Additionally, Sykes mentions Soviet Premier Nikita Khrushchev by name in this song, which acknowledges the Cold War overtones of the new technology. Another example of *Sputnik* in the Blues is Harmonica George's 1959 "Sputnik Music."[41] Though instrumental, the title of this track certainly indicates a distinct awareness of world events.

But not all of the songs about Sputnik were so lighthearted or playful. Some of them expressed serious concerns and fears toward the idea of the Soviet Union's actions, as you can hear

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[36] Billy Lee Riley, "Red Hot" available at: https://www.youtube.com/watch?v=Nxt_7sD9znM (accessed June 12, 2015) and Billy Lee Riley, "Flying Saucer Rock 'n' Roll" available at: https://www.youtube.com/watch?v=CIlYMPeA0sg (accessed June 12, 2015).

[37] Carl Mann, "Satellite No. 2" available at: https://www.youtube.com/watch?v=XB9Vgbhu7Dw (accessed June 12, 2015)

[38] Other examples include Jerry Engler, "Sputnik" available at: https://www.youtube.com/watch?v=TxH_M-WJ9_0;
Nelson Young, "Rock Old Sputnik" available at: https://www.youtube.com/watch?v=mZb1boVtKXc;
The Equadors, "Sputnik Dance," available at: https://www.youtube.com/watch?v=I_fARQcrL6c;
Al Barkle, "Sputnik II" available at: https://www.youtube.com/watch?v=1K6zN5tdSO4;
Bill Thomas, "The Sputnik Story" available at: https://www.youtube.com/watch?v=aR2c24mxKsA;
Joe Tate, "Satellite Rock" available at: https://www.youtube.com/watch?v=biH--wA-J0U;
The Rebelaires, "Satellite Rock" available at: https://www.youtube.com/watch?v=lurYPIPMHew;
The Satellites, "Satellite Bop" available at: https://www.youtube.com/watch?v=Va5bNAoTj1o;
Skip Stanley, "Satellite Baby" available at: https://www.youtube.com/watch?v=4lMjwirgxGc;
Warren Scott and the Memphic Playboys. "Rocketship Mama" available at: https://www.youtube.com/watch?v=XXHu2EEO_Jw;
Bill Fadden and the Silvertone Flyers, "Satellite Rock" available at: https://www.youtube.com/watch?v=HlqxUFMmJX4;
and Jimmy Copeland & the J-Teens, "Satellite Rock" available at: https://www.youtube.com/watch?v=Yhi7qmfW3Wg (accessed June 15, 2015).

[39] Roosevelt Sykes, "Satellite Baby" available at: https://www.youtube.com/watch?v=hdfiB3y6bTA (accessed June 15, 2015).

[40] Robert Johnson, "Terraplane Blues" available at: https://www.youtube.com/watch?v=dloPrGI0EuY (accessed June 15, 2015)

[41] Harmonica George, "Sputnik Music" available at: https://www.youtube.com/watch?v=EDNaK0WeZRI (accessed June 15, 2015).

here from Ray Anderson, a bluegrass singer from rural West Virginia, who recorded this song, "Sputniks and Mutniks," in 1958:

Sputniks and mutniks flying through the air
They're so ironic
Are they atomic?
Those funny missiles have got me scared.[42]

Some of the songs which expressed concern about space exploration were deeply rooted in religious skepticism. Dora Alexander was a gospel street singer in the French Quarter of New Orleans who folklorist Sam Charters recorded in 1958. Her song "Russia, Let God's Moon Alone" conveys that the moon is God's sacred territory and therefore no place for humans.[43] "The moon ain't worryin' you", she sings. Again, this song illustrates an understanding of the global politics that were unfolding around the space age. Her religious skepticism is matched with a skepticism of the Soviet actions.

As the U.S. became further involved in the space race, southerners wrote songs which both critiqued and embraced the idea.[44] One example of a positive response is a song written by legendary Texas bluesman Lightnin' Hopkins, "Happy Blues for John Glenn."[45] Hopkins seems to have penned the song as a congratulatory statement for the astronaut who flew three times around the globe in 1962 becoming the first American to orbit the Earth. On the other hand, the song might include a little tongue-in-cheek humor, implying that money was Glenn's major motive for his expedition: "That half a million dollars made him feel so well." The rockabilly track "Shake it over Sputnik" by Billy Hogan is another example of this type of reaction.[46] The song is a celebration of Werner von Braun's Huntsville, Alabama team ("a bunch of brains from across the pond") that developed the *Juno I,* which launched *Explorer I* the United States' first Satellite in 1958. Hogan declares this "Alabama's contribution to the conquest of space."

One of the most famous examples of a harsh musical critique of the space race was written by Gil Scott-Heron, the great Harlem jazz poet who had been raised in Jackson, Tennessee. "Whitey on the Moon" sets up a valid contradiction between the US government's involvement in

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[42] Ray Anderson & the Home Folks, "Sputniks and Mutniks" available at: https://www.youtube.com/watch?v= 4tTXu6hkCm0 (accessed June 15, 2015). Another interesting example of Anderson's politicized country music can be found in "Stalin Kicked the Bucked" available at: https://www.youtube.com/watch?v=9O7doMD89NI (accessed June 15, 2014).
[43] Dora Alexander, "Russia, Leave God's Moon Alone" available at: https://www.youtube.com/watch?v=Sn8PPidkw5I (accessed June 15, 2015).
[44] The open critique of the space program can be contrasted against the songs of the Soviet Union which "were specifically about the heroic adventures of the cosmonauts." Marilyn Dudley-Flores and Thomas Gangale, "Public Moods Toward Space Through Analysis of Popular Music: An Astrosociological Application," *Aerospace America*, 2, 2010, http://ops-alaska.com/publications/2010/2010_PublicMoodsTowardSpace.pdf.
[45] Lightnin' Hopkins, "Happy Blues for John Glenn" available at: https://www.youtube.com/watch?v=Sn8PPidkw5I (accessed June 15, 2015).
[46] Billy Hogan, "Shake it Over Sputnik" available at: https://www.youtube.com/watch?v=fdtYBO1Dm7E (accessed June 15, 2015).

space exploration and its lack of concern for the health and well-being of impoverished African Americans living in urban ghettos.[47] He directly attacks the inequality in expenditures on the space program and the returns for individuals. His critique is rooted in race and class, and draws attention to the plight of individuals who presumably have not benefited from this globalized technology. "Whitey on the Moon" is interesting because the critique is divorced from Cold War narratives and focused on how global technology has failed to raise local living standards.

A very similar theme resonates in a more recent song by the Alabama based indie rock band The Drive-By Truckers, "Putting People on the Moon," which again sets up a strain between relevant socioeconomic problems and the amount of money spent on the space program.[48] "Putting People on the Moon" inhabits a particularly regional gaze, as the singer Patterson Hood (who's from northwestern Alabama a historically impoverished area adjacent to Huntsville, Alabama where the Marshall Space Flight Center was established in 1960) describes the life in a rural Alabama:

Double Digit unemployment, TVA be shutting soon

While over there in Huntsville, They puttin' people on the moon.

The narrative is set in the 1980s ("Goddamn Reagan's in the White House") and as a result matches themes adopted by Scott-Heron. Highlighting the lack of political interest in those outside the pale of technological advances, both artists call into question whether space really is being used for the "benefit of all mankind."

V. Understanding the Southern Construction of the Space Age

The space narratives reflected in southern music help to illustrate two dominant points about how the space age was and is reflected in southern culture. A primary observation is that rather than reflecting a stereotype of agrarian backwardness and technophobia, these songs reflect a culture that is in conversation with emerging global culture and politics and that is being shaped by the advances of the space age. This reflects southern society's role as a participant in space exploration, such as was seen in "Shake it over Sputnik."[49] Far from technophobic, much of this music embraces scientific discovery and wonder, and touts American achievements. Maybe one of the emblematic images of this is the cover of Elvis Presley's 1973 album *Aloha from Hawaii via Satellite*, which features a telecommunications satellite prominently on the cover.[50] Presley, a

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[47] Gil Scott-Heron, "Whitey on the Moon" available at: https://www.youtube.com/watch?v=goh2x_G0ct4 (accessed June 15, 2015).

[48] Drive-By Truckers, "Putting People on the Moon" available at: https://www.youtube.com/watch?v=xeYGo33_wkY (accessed June 15, 2015). The Drive-By Truckers also address this same North Alabama setting in the mournful "Space City," in which Huntsville stands as an emblem of false hope from technological advances "Space City's one hour up the road from me /Its one hour away from as close to the moon as anybody down here's ever gonna be." Drive-By Truckers, "Space City" available at: https://www.youtube.com/watch?v=LbzfpSPKAwY (accessed June 15, 2015).

[49] *Supra* note 46.

[50] Elvis Presley, *Aloha from Hawaii Live Via Satellite* (RCA 1973).

Mississippi native and arguably one of the world's first truly international superstar, has adopted an album cover and title that explicitly acknowledges the technology that made international stardom possible.

A second observation is the degree of political motivation within the songs. When skepticism is the theme, it generally cuts along political boundaries. Even religious songs like "Russia, Leave God's Moon Alone," reflect an acute awareness of the Cold War.[51] Other songs use the Space Age to illustrate for both racial and social inequality, but the emphasis is on the opportunity gap for technology as opposed to being anti-technological advancement. The strong political themes in these songs denotes a recognition that technology is political, a theme that is likely reflected in similar southern narratives about railways and farming.

The Space Age reflected through southern culture, therefore, is a network of ideas that reflect a complex understanding of what space exploration meant both at the global and local levels. These layers of meaning cut across religion, science, and politics and create a southern awareness that the world was changing and what that meant. It also reflects the unique southern experience of seeing firsthand the paradox of the wealth involved technological innovation sited next impoverishment.

VI. Conclusion

Space remains a theme in southern music today with many artists still exploring the theme across a variety of genres. This article stops short of a full survey of southern music and focuses primarily on music that coincided with the Cold War and the Space Race. This is, in part, a noted peak in songs about space in the 1960s.[52] There is much more music to be investigated.[53] While modern southern music, aside from the Drive-By Truckers as noted above, lacks many of the political overtures, space themes still play an important role in this music. Much of it focuses on the wonder and excitement of exploring the unknown, such as the psychedelic explorations found in songs like Widespread Panic's "Space Wrangler"[54] or the cosmic instrumentals such as the Mystery Men's "Preparation Space."[55]

Indeed, themes of exploration have strong roots in jazz with Sun Ra's cosmic philosophy that played out through his various recordings. The exploratory nature of jazz lends itself to absorbing the space metaphor in the creation of audio landscapes. However, the political themes of African American music have not been completely abandoned. Sun Ra's instrumental jazz was complimented by a series of lectures that he gave at UC Berkeley titled "The Black Man in the

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[51] See also Rijn, *supra* note, 116, 124-126.

[52] Dudley-Flores and Gangale, "Public Moods," *supra* note 44, at 2.

[53] Indeed, Dudley-Flores and Gangale note a similar peak in the production of space music in the 1990s and 2000s. Dudley-Flores and Gangale, "Public Moods," *supra* note 44, at 3. Southern examples include Widespread Panic, "Space Wrangler," (1988); The Mystery Men, "Preparation Space," (2011); Irvin Mayfield, "Moonscape" (2003); The Flaming Lips, "Watching the Planets" (2009); Outkast, "E.T. (Extraterrestrial)" and "ATLiens" (1996); Drive-By Truckers, "Space City" (2006).

[54] Widespread Panic, "Space Wrangler" available at: https://www.youtube.com/watch?v=BJUriJqTG9M (accessed June 15, 2015)

[55] Mystery Men, "Preparation Space" available at: https://www.youtube.com/watch?v=aIVJVPIbDww (accessed June 15, 2015)

Cosmos" in 1972.[56] Sun Ra's brand of Afrofuturism is still reflected in works such as Outkast's *ATLiens*.[57] This album uses space themes to indicate the alienation and isolation of African Americans in southern culture (indicated by the "ATL," an abbreviation for Atlanta, Georgia). Space maintains its place as a metaphor for both exploration and external isolation.

As space exploration has become more and more common and integrated into society, space themes have continued, but they now tap into common understandings of technology. Instead of addressing major political changes and upheaval, space in southern music now reflects the integration of the technology into everyday life in a spacefaring society. Perhaps the best example of this is the Alabama surf rock group Man or Astro-man? The band's name itself problematizes the question of the status of humankind in the space age.[58] This is coupled with consistent science fiction themes across the band's music and artwork, which indicates a full engagement in the cultural aspects of a spacefaring society.

Of course, the question of "man or astro-man?" is a binary simplification that queries identity. As the Space Age dawned, it became intermingled with terrestrial social structures, and in the South the Space Age entered into a landscape of complex constructions of identity built around deep historical structures involving race and gender.[59] This brief article seeks to give a window into the cultural production that resulted as these phenomena interacted, but it truly only scrapes the surface of such representations. Music is just a small facet of the picture, and it is hoped that this research will be useful to related studies that seek to understand how the project of space exploration was represented across a range of cultural artifacts.

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[56] See "Sun Ra's Full Lecture & Reading List From His 1971 UC Berkeley Course, "The Black Man in the Cosmos," *Open Culture* (July 21, 2013): http://webcache.googleusercontent.com/search?q=cache:http://www.openculture.com/2014/07/full-lecture-and-reading-list-from-sun-ras-1971-uc-berkeley-course.html.

[57] Outcast, *ATLiens* (LaFace Records 1996).

[58] The theme of transhumanism is one that is often found in the social sciences literature of space. *See generally*, George S. Robinson, "Addressing the Legal Status of Evolving 'Envoys of Mankind,'" Annals of Air and Space Law 36 (2011): 447–512.

[59] *See generally*, P.J. Blount and Dave Molina, "The Distance from the Ghetto to the Moon: Contextualizing the Space Program in the Discourse of the American Civil Rights Movement," in Brian Odum, ed., *NASA and the Long Civil Rights Movement* (tentative) (forthcoming Florida State University Press 2018).

Postcards from the Cosmos: Cosmic Spaces in Alternative Religion and Conspiracy Theories

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ABSTRACT - If conspiracy theory is the narration of fears of existential dread, of a potentially apocalyptical plot against "us," then we can understand alien conspiracies as a dread of the coming of "cosmological humanity" and the end of "geostationary man." In escaping gravity's hold a terminal velocity is achieved by a species ready to mythologize, even sacralize, its achievements, and to enchant the heavens once again in terms more suited to the technological age. Virgiliu Pop's astrosociology will provide a means for framing the uniqueness of post-Gagarin conspiracist spiritualities within the particular religious cultures of cosmic humanity while Raymond Williams' concept of "structures of feeling" will be drawn upon to understand the cultural significance of these spiritualities.

I. Introduction

This article will provide a commentary on the "cosmic turn" taken by marginal beliefs following humanity's discovery of space flight. Yuri Gagarin's successful orbit of the Earth in 1961 will be used for its symbolic value as the moment in which the possibility of the "space age" was realized through the presence of human life beyond Earth's atmosphere. There is no claim as to it being a direct inspiration for the movements discussed here but rather that its connotative resonances provide a means for understanding the context that has given rise to these religious constructs. Certainly, the founding of the Aetherius Society predates Gagarin's flight and there are earlier examples of "cosmic new religious movements": Ron L. Hubbard's Dianetics movement, and subsequently, Scientology; or Dorothy Martin's Chicago believers group (made famous in Leon Festinger's study *When Prophecy Fails*) are two well-known examples. From Joseph Smith's time onwards, various forms of Mormonism have made claims that life was created on other planets and this has led to speculation within the church about the concept of a populated multiverse.[1] Additionally, there are many antecedents of a supranormal meaning being attached to material cosmic incursion into the human sensory range. For instance, since at least Aristotle's time, Halley's Comet has been associated with signs and divination.[2] During the last century, post-World War II UFO "scares" have mobilized diverse public responses and the most notable have left an enduring cultural legacy. George Adamski's claims to have encountered alien "Space Brothers" began in the late 1940s, predating the well-known story of the alleged crashed UFO at Roswell,

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[1] Kirk D. Hagen, "Eternal Progression in a Multiverse: An Explorative Mormon Cosmology," *Dialogue: A Journal of Mormon Thought*, vol. 39, no. 2 (Summer 2006) pp. 1–45.

[2] For an excellent overview see Sara J. Schechner (1999) *Comets, Popular Culture, and the Birth of Modern Cosmology*. Princeton: Princeton University Press.

New Mexico during July 1947. In some ways, the Roswell account might have served as an alternative to Gagarin's flight as a powerful symbolic moment in the proliferation of cosmic new religious movements, given its influence on the UFO flap of the late 1940s and 1950s.[3] Nonetheless, Gagarin is used here because, as shall be argued, his flight represents the breaching of a barrier that no human had previously physically crossed and ushered in a new relationship with the cosmos.

Yuri Gagarin's 1961 spaceflight extended the range of humanity in a way that profoundly rewrote our relationship with the heavens. Pioneering sociologist Émile Durkheim wrote, regarding the incommensurability of the sacred and the profane, that "[t]he sacred thing is, par excellence, that which the profane must not and cannot touch with impunity. This prohibition surely makes all communication impossible between the two worlds; for if the profane could enter into relations with the sacred, the sacred would serve no purpose."[4] While Durkheim's observation is more honored in the breach, it provides a spatial understanding of sacrality that helps to convey the *religious* implications of Gagarin's flight. First Sputnik and then, most profoundly, Yuri Gagarin took humans into heaven and revealed it to be vast and apparently indifferent to humanity. His voyage revealed the fragility of the divide between the sacred and the profane; Earth and the heavens were materially in reach of one another. Prior to Gagarin's flight, human journeys into "the heavens" had been out of body, in spirit form alone, but his flight took humanity – in body – into the realm of the gods. In this article, Gagarin's voyage is used as a highly charged symbolic moment that demarcates between man-beneath-the-heavens and man-in-space. Clearly, it is part of a longer history of space flight and human exploration but the drama of the moment carries a semiotic ripeness that provides a focus for a key period of human expansion.

It is argued here that humanity has, since then, failed to reconcile itself to the idea of being a cosmic species, that the capacity to incorporate this expanded awareness of humanity's "place" into human cultures – and beliefs – is yet to become fully manifest. Virgiliu Pop[5] and Carol Mersch[6] both chart human attempts to export earthly religions to space: to fill the heavens with earthly religions, the Russian and American space programs contained within their scientific practices the seeds of earlier forms of belief. Mersch concluded that this was reflective of NASA astronauts as explorers, wishing to take the old world into the new, of a "spiritual expression that is intrinsic to human beings in the act of exploration";[7] while Pop described cosmonauts decorating the walls of the Mir space station (and, later, the International Space Station) with icons in the wake of the post-Communist revival of Russian Orthodoxy. Compellingly, Pop weaves Gagarin into the fabric of Russian cosmism[8] and, particularly, the cultural vacillation of the figure of Gagarin between Communist atheism and Russian Orthodoxy. With its roots in the technological utopia in space imagined by Nikolai Fedorov and the spaceward trajectory of human evolution predicted by Konstantin Tsiolkovsky, cosmism represents an early sacralization of "secular space."

[3] David Clarke & Andy Roberts (2007) *Flying Saucers: A Social History of UFOlogy*. Loughborough: Heart of Albion Press.
[4] Émile Durkheim, *The Elementary Forms of Religious Life*, trans. Carol Cosman. Oxford: Oxford University Press, 2001, 39.
[5] Virgiliu Pop, "Viewpoint: Space and Religion in Russia: Cosmonaut Worship to Orthodox Revival," *Astropolitics: The International Journal of Space Politics & Policy* 7, no. 2 (2009): 150-163.
[6] Carol Mersch, "Religion, Space Exploration, and Secular Society," *Astropolitics: The International Journal of Space Politics & Policy* 11, no.1-2 (2013): 65-78.
[7] Mersch, "Religion, Space Exploration, and Secular Society," 76.
[8] Pop, "Viewpoint: Space and Religion in Russia: Cosmonaut Worship to Orthodox Revival."

In his concluding comments, Pop describes the duality of Gagarin's legacy in a way that points to the manner in which Gagarin can be understood to have simultaneously demystified but yet re-enchanted the cosmos:

> Aboard the ISS, close to the Orthodox Icons, lays the photograph of Gagarin. He deserves to be there, not as a demigod of the atheist faith, but as the first human being having stepped upon the celestial path. His picture may be an icon for the cosmists and for the atheists, yet for those believing Christian Orthodoxy [*sic*], Gagarin holds a special place. The human being, made according to the image of God, is himself a 'living icon of God.' Unaware of this, by sending Gagarin to outer space, the godless communists were the first to launch an Orthodox icon aboard a spaceship.[9]

Pop captures the paradoxical multi-valency of Gagarin as a symbol of space exploration. A living icon on the "celestial path," his flight into the "beyond" was achieved through the efforts of the "godless communists." In a moment of transcendence, Gagarin revealed humanity's material basis and longing for something beyond the material. Elsewhere Pop articulates the unpreparedness of the bulk of humanity to expand their conceptual range in order to accommodate this moment.[10] He characterizes this as humanity being caught between "future shock" (Alvin Toffler) and "cultural lag" (William Ogburn). Pop's account sketches a pattern of responses within folk cultures around the world in which "cosmological humanity" is blamed for crop failure, natural disasters, and a damaged ecosystem:

> 'Because of what you have done'—said Richard Nixon to the Apollo astronauts—'the heavens have become a part of man's world.' To those who deemed the Moon as the realm of divinity, the human conquest of outer space and of the Moon meant their literal desecration, their passage from sacred to the profane. Such an act of taking into human possession what was before heaven, of depriving the Moon of its sacred character, could not go unpunished.[11]

Durkheim provides a useful conceptual metaphor here: the profaning of the sacred in a moment of transcendence. The evolution of humanity into a space-faring species, then, is the source of both fear and wonder – of living icons and of cataclysmic threats. And it is the human world, of culture and belief, in which this is played out. Here then, in this article, the context of the journey from the profane into the sacred provides the context in which spiritualized UFO conspiracies can be understood.

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[9] Pop, "Viewpoint: Space and Religion in Russia: Cosmonaut Worship to Orthodox Revival," 160.
[10] Virgiliu Pop, "Space Exploration and Folk Beliefs on Climate Change," *Astropolitics: The International Journal of Space Politics & Policy,* 9, no.2 (2011): 50-62.
[11] Pop, "Space Exploration and Folk Beliefs on Climate Change," 59.

II. Apocalyptic Spaces

Moshe Barasch's consideration of the role of space and location in Western apocalyptic discourse identifies the importance of the vertical plane in depictions of apocalyptic space and it is this verticality that Gagarin traversed.[12] Barasch provides a powerful summary of the complexity of this vertical dimension,

> [T]he ascension to heaven is the manifestation of celestial origin [and yet] carries soteriological connotations. The ascension to heaven is a formula for salvation […] The narration of a dramatic descent into hell leading to a struggle between the 'superior' and the 'inferior' forces and ending with the victory of salvation, is of course a typical apocalyptical motif.[13]

In that flight, humanity broke free of gravity's fetters but also re-enacted this bi-directional motif that Barasch also describes as "an essential component of the [apocalyptic] theme."[14] Gagarin's flight is thus symbolically charged with the cataclysmic dimension that Pop identified among global folkloric cultures. Further, it precipitated an outpouring of cosmically oriented new religious movements (NRMs) and spiritualities and these space age religions retain the eschatological verticality, that is to say the passivity of thinking about the unraveling of collective destiny in spatial terms, which Barasch identifies. The figure of spiritualized space is contradictory; to journey into it is simultaneously heretical and transcendent. Barasch delineates the topology of apocalyptic space and we can map Gagarin's flight within it.

Gagarin's flight is apocalyptic: revelatory and cataclysmic, it profanes the heavens and reveals the end of one history of humanity and the initiation of a new, unbounded humanity. The pre-Gagarin heavenly spaces are brought closer and the traditions with which Barasch is primarily concerned still shape post-Gagarin reappraisals. Space continues to be the source of both judgment on humanity and also its subsequent punishment; accordingly, the Judaic motif of a powerful entity punishing those lacking commitment to the faith continues to shape a number of post-Gagarin NRMs.

The motif was present in the beliefs of Heaven's Gate. The Heaven's Gate group was a small new religious movement based in California. The group was co-founded by Marshall Applewhite and Bonnie Nettles in their native Texas and grew as they spread their hybrid message of a UFO-enabled Christian millennialism. Following Nettles' death in 1985, the group became increasingly focused on the charismatic leadership of Applewhite. Leaving one member to maintain their website, thirty-eight members ("the crew") and Applewhite took their own lives during the third week of March 1997 in the belief that they were ready to evolve to a higher level of consciousness. They claimed that they were ready to attain "The Evolutionary Level Above Human" and would be reconstituted on an alien spacecraft hidden in the tail of the Hale-Bopp comet as it passed close to Earth. They would remain there while the Earth was "recycled." This transit to an

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[12] Moshe Barasch, "Apocalyptic Space," in *Apocalyptic Time*, ed. Albert I. Baumgarten, 305-326. (Leiden: Brill, 2000).
[13] Barasch, "Apocalyptic Space," 322.
[14] Barasch, "Apocalyptic Space," 322.

imagined spacecraft behind the Hale-Bopp comet was, at once, a transcendence to a new level of consciousness and also – through this quasi-Rapture – an escape from a cataclysmic judgment on Earth. Benjamin Zeller's account of the awkwardness of the New Age Biblical hermeneutic, or the interpretative framework, driving Heaven's Gate points to the difficulty of negotiating the culture shock and cultural lag described above.[15] The premillennial dispensationalism that shaped the structure of Heaven's Gate eschatology[16] represents the old world of Christian discourse, while the environmental factors and the UFO technologies behind the translated rapture event reflect the shockwaves of the culture shock described by Pop. "Avenging space" in new religious cosmologies is a place of fear but also redemption. Heaven's Gate was a product of the cultic milieu but, nonetheless, shared structural similarities with Judeo-Christian eschatology and the apocalyptic vertical plane that Barasch identified.

III. Alien creators

Alongside this structurally familiar depiction of destructive deistic space entities there are contemporaneous forms of sacralized near and outer space that describe space as the source of life on Earth and the physical and spiritual location of the "truth" of existence. In these accounts, Earth's fragility is still evident but so too is its integration into the "cosmic whole." It is in these that post-Gagarin spiritual forms are most clearly articulated. NRMs of the enchanted cosmos vary widely but are unified by situating Earth within a narrative of an inhabited universe in which terrestrial life is at an uninformed and undeveloped stage. Typically, cosmic truth is "out there" and revealed to chosen ones via direct visitation or psychic revelation. Raëlianism and the Aetherius Society typify both revelatory traditions.

On Thursday, December 13, 1973, Raël (b. Claude Vorilhon, 1946) claims to have been visited by an "alien" on a dormant volcano top in the Clermont-Ferrand region of France. During this and subsequent evenings, the humanoid aliens ("Elohim") allegedly recounted the truth of humanity's creation to Raël and then, on Tuesday, October 7, 1975, he claims to have received another visitation. On this occasion, he believes he was taken to the home planet of his otherworldly contacts. In Raël's account, he makes the claim that the Elohim are advanced scientists from another world who had used Earth as a laboratory; the details of their experiments were recorded in Genesis and other books of the Old Testament. The Raëlian philosophy is presented as if it were a true account of life on Earth's material, extra-terrestrial origin. While Susan Palmer (2004) straightforwardly describes Raëlianism as a religion,[17] George Chryssides describes them as "scientific creationists."[18] This is, perhaps, a more representative appellation as it combines the scientism that Raël directly makes claim to while connoting the theological resonances of his creation story. Raël's philosophy is certainly atheist and eschews occult forces; the Raëlians describe

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[15] Benjamin E Zeller, "Extraterrestrial Biblical Hermeneutics and the Making of Heaven's Gate," *Nova Religio: The Journal of Alternative and Emergent Religions,* 14, no.2 (2010): 34-60.

[16] For example, Christopher Partridge, "The Eschatology of Heaven's Gate," in *Expecting the End: Millennialism in Social and Historical Context*, ed. Kenneth G. C. Newport and Crawford Gibbons, 49-66. (Waco, TX: Baylor University Press, 2006) and Zeller, "Extraterrestrial Biblical Hermeneutics and the Making of Heaven's Gate."

[17] Susan Palmer, *Aliens Adored: Raël's UFO Religion.* (New Brunswick, NJ & London: Rutgers University Press, 2004).

[18] Chryssides, George D. "Scientific Creationism: A Study of the Raëlian Church," in *UFO Religions* ed. Christopher Partridge, 45-61, (London: Routledge 2003).

themselves as an "atheist religion," stressing the role of their movement in creating a link between humanity and "the Creators."[19] Raëlian space is infinite, so too is life in the universe: "The universe being infinite, there is an infinite number of inhabited planets and an infinite number of Elohim and creations."[20] The ambiguity of Raël's position is made evident in his continued use of the Hebrew term for Gods or gods, *Elohim*. Although he is keen to stress the secular materiality of his universe, his ongoing use of the term charges it with a connotated divinity. The Raëlian universe is also multiple with a series of infinitely recursive nested realities: the cells of our bodies are, themselves, separate universes.[21] Here, then, the enchanted cosmos has entered the fiber of our being; we are not just revealed to be part of the greater cosmos but contain the cosmos within us.

IV. <u>Esoteric Aliens</u>

The Aetherius Society typifies a world-accommodating NRM and also one that has successfully sustained its membership after the death of its founder. With an indebtedness to Theosophy, Aetherian belief provides continuity between pre- and post-Gagarin NRMs and develops a vastly enlarged iteration of Blavatsky's system. The Aetherius Society was founded in 1955 by Dr. George King (1919-1997). King claimed to have received a psychically transmitted auditory message from Master Aetherius, an advanced extraterrestrial intelligence who first contacted King in 1954. In King's account, Aetherius was the Venusian representative of a cosmic organization called the Interplanetary Parliament, a non-political advisory council made up of representatives from within and beyond our solar system and which convened on Saturn. In King's account, Aetherius contacted King to name him as the voice of the Interplanetary Parliament on Earth and to spread its spiritual and technological messages.[22] Where Raëlianism is idiosyncratic, Aetherianism is typical of post-World War II UFO religions in its indebtedness to Theosophy; it developed Theosophy's "cosmic evolution" and exported the hidden masters to other worlds. Like Raëlianism, a populist understanding of science is a key element of Aetherian philosophy and King espoused a "fuller" version of science and religion that fused both. In Aetherian belief, each of the solar planets are inhabited but at different levels of vibration. These cannot be perceived by humans as our senses are only attuned to "level 1" vibrations. Cosmic Masters are capable of perceiving multiple frequency vibrations "because of their highly sensitized [*sic*] or psychic senses as well as advanced instruments. Because of their advancement they are able to move through one realm of existence on to another frequency both on this Earth and outside of it with great ease."[23] Ordinary souls ("lifestreams") can evolve up, or devolve, to other planetary existences with each planet in the solar system being characterized by distinct forms of intelligence that souls acquire through experience. The lifestreams on Earth were made homeless by their destruction of their home planet, Maldek – now the asteroid belt between Mars and Jupiter. "Mother Earth" took pity on the lowly lifestreams and provided them with a home. Here, again, it is possible to discern the

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[19] International Raelian Movement, "FAQ #8: Do Raelians Consider Raelianism as a Religion?" Message from the Designers, last modified, April 20, 2013. http://www.rael.org/e107_plugins/faq/faq.php?cat.1.8
[20] Raël Maitreya, in a Facebook message to the author, July 11, 2014.
[21] Raël, Facebook message to the author.
[22] For more detail on the beliefs of the Aetherius Society see John Saliba, "The Earth is a Dangerous Place – The World View of the Aetherius Society", *Marburg Journal of Religion*, 4, no.2 (1999): np. https://www.uni-marburg.de/fb03/ivk/mjr/pdfs/1999/articles/saliba1999.pdf.
[23] Ayub Malik, Aetherius Organizer, in an email to the author, July 16, 2014.

spatial reckoning of cataclysm and salvation as described by Barasch. The apocalyptic spatiality that he describes is reiterated in a new, cosmic setting. Like Raëlians, Aetherians are unthreatened by scientific advances, seeing them as confirmation of prior revelations:

> [W]e welcome such discoveries. We have been told that if we are to really advance in such discoveries, more than we have done to date, we have to change our motives and become more spiritual. [...] Discoveries outside of this planet are important but what is more important is to put right conditions on this planet.[24]

V. <u>Intrusive Aliens</u>

On their own terms, the beliefs of Raëlianism and Aetherianism render space knowable, acting as a bridge between human perception and cosmic truth; the spiritualization of space is a projection of human narratives onto the inhuman. Alien NRMs reflect a changing relationship with space. Where heaven was a distant endpoint, sacred space is proximate, dynamic, and prone to intersect with terrestrial experiences. Following Auguste Comte, Durkheim provided a useful framework for understanding religion as the deification of society by its subjects; from this understanding, it can be suggested that as the extent of the social comes to incorporate the cosmos we deify and worship our own capacity to inhabit and to "know" space.

For Jodi Dean, UFO abduction narratives hold a similar effect; while not disputing the perceived reality that the abduction events have for the abductees, Dean delineates the source of the fascination that the abduction narrative has within wider culture. She describes a particular modern sense of diminished agency and an unrepresentative politics in which power is always outside of the body politic but always operative within it.[25] The abductee thus encapsulates this feeling of powerlessness. They are taken against their will, manipulated, experimented upon, vital fluids extracted, and alien objects inserted. Their bodies and minds are familiar and yet not wholly their own. She writes,

> In abduction, the alien takes away our agency, and the sense of security and certainty upon which our agency was predicated. This theft of agency is manifest not just in the power of the alien to paralyze us and abduct us at will, but also in its technological superiority.[26]

In Dean, alien abduction narratives encapsulate the anxiety of an age in which agency and the boundaries between once accepted norms of belief, self, and identity are under continuous assessment and negotiation. Further to this, not only does alien abduction spatially dislocate us and rob us of our capacity to be self-determining, but it also intervenes in and reformulates our bodies. For Dean, the consistency we invest in our place in the world is undermined, as is the

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[24] Malik, email to the author.
[25] Jodi Dean, *Aliens in America: Conspiracy Cultures from Outer space to Cyberspace.* Ithaca, NY: Cornell University Press, 1998.
[26] Dean, *Aliens in America*, 174.

blueprint of our identity; our sense of belonging in what were "our" exterior and interior worlds is no longer guaranteed. Barbara Brown makes a similar point. Her concerns are similar to Dean's and she recounts the symbolic qualities of Betty and Barney Hills' archetypal abduction experience.[27] In 1963, while under hypnosis, the Hills "recovered" memories of being abducted by aliens two years earlier. During their time on the alien craft, the Hills claimed to have been made the subjects of medical experimentation with Betty recounting having a range of samples taken and the insertion of a large needle into her naval, and Barney being anally probed and his semen being extracted.[28] Brown interprets the Hills' experience in a similar way to Dean's treatment of alien abductions in general: she sees the abduction and examinations as a powerful articulation of the limited nature of agency in late modernity.[29] Brown explicitly links the emergence of alien abduction narratives to advances in medical technologies, particularly technologies of reproduction. She describes, "The collective anxiety expressed by these abductees about the encroachment of technology into 'natural' human functions;" an encroachment which is simultaneously, "alienating and awesome," but which reveals the disconnectedness of medical subjects from the processes enacted upon them, sharing with abductees a subjectivity characterized by feelings of being "confused and powerless non-experts."[30] The spatiality of abduction is vertical but unstructured: the trajectory is the same but the journey here has little of the willed coherence of Gagarin's and also fails to contain any salvific promise. Instead it offers lost memories, a loss of autonomy, and a sense of diminished agency in light of an overwhelming and distant power.

VI. The Role of Conspiracy Theory

The loss of agency that alien abduction is treated as a cypher for is also a theme in academic treatments of conspiracy theory. Fredric Jameson, for example, suggests that conspiracy theories mark a populist mapping out of the experiences of powerlessness and a desire to confront and comprehend the totality of a global system that is otherwise impossible to understand.[31] In the face of the complexity of an ever-expanding global capitalism, Jameson argues, there is little by way of a popularly available critical stance or culturally common systems of representation that are able to render current global realities meaningful. Jameson suggests that it is only in war and colossal natural disasters that we are able to consider our globality; all other representative systems are otherwise geared to the national-local. Jameson suggests in *Postmodernism* that our systems of representation have broken down and the very possibility of referentiality has become undermined.[32]

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[27] Bridget Brown, "'My Body Is Not My Own': Alien Abduction and the Struggle for Self-Control," in *Conspiracy Nation: The Politics of Paranoia in Postwar America*, ed. Peter Knight, 107-129, (New York: New York University Press, 2002).
[28] John G. Fuller, *The Interrupted Journey: Two Lost Hours "Aboard a Flying Saucer"*, New York: The Dial Press, 1966.
[29] Bridget Brown, "'My Body Is Not My Own': Alien Abduction and the Struggle for Self-Control."
[30] Bridget Brown, "'My Body Is Not My Own': Alien Abduction and the Struggle for Self-Control," 116.
[31] Fredric Jameson, "Cognitive Mapping," in *Marxism and the Interpretation of Culture*, ed. Cary Nelson and Lawrence Grossberg, 347-360, (Urbana and Chicago: University of Illinois Press, 1988).
[32] Fredric Jameson, *Postmodernism, or, the Cultural Logic of Late Capitalism,* London: Verso, 1991.

Conspiracy theory is therefore, crucially, an attempt at representing the "total logic of late capital," where no other means are available. This situates conspiracy as a narrative – a representational mode – essentially a story, by means of which the excess of signifiers that proliferate in postmodernity can be tied to a small and manageable number of signifieds. So, it is, then, that for Jameson accounts that narrativize and provide coherency to an otherwise incomprehensible situation provide the opportunity for meaning regardless of how limited and apparently irrational that meaning may be. The seven-foot tall shape shifting lizards of David Icke's cosmic conspiracy are easier to grasp than the intangible, overwhelming, and ever shifting movement of global capital. In other words, conspiracy forces all complexities and contradictions to resolve themselves within the hermeneutic framework established by the terms of the conspiracists' narratives. In this sense, we can understand the usefulness which Jameson saw in the figure of "mapping" as the conspiracists draw a map of the conditions of life in postmodernity. In Jameson's understanding, this is not the universal agency loss found in Dean and Brown but particular and class-based: "Conspiracy is the poor person's cognitive mapping in the postmodern age; it is a degraded figure of the total logic of late capital, a desperate attempt to represent the latter's system."[33] Degraded it may be but despite this and in spite of the total system of alienating domination, Jameson still recognizes a utopian impulse in conspiracy. Mark Fenster confirms Jameson's approach and recognizes the political structuration of the conspiracy narrative's organization of a totalized and fully integrated economic, cultural, social, and political totality.[34] Because of the importance that conspiracy theorists allot to revealing to the alienated "sheeple" the conspiracy orchestrating this totality, there is a claim to agency, of the reinsertion of the individual subject into history:

> [I]n its attempt to reveal a hidden truth that challenges the alienated social conceptualized within classical liberal thought, the conspiracy represents a utopian desire to reflect upon and confront the contradictions and conflicts of the contemporary democratic state and capitalism.[35]

Conspiracy betokens a lack of understanding and a naïve utopian impulse in Jameson's reading; however, here Fenster extends this to consider conspiracy as an enabler of agency. Just as in Dean's assessment of alien abductions, Fenster draws out the crucial element of narrative building that conspiracy theory provides while also being cognizant of its capacity to insert the conspiracy theorist as an active agent of resistance, at least within the terms set out by the conspiracy theorist. Fran Mason counters Jameson's take on conspiracy theory by suggesting that there is considerable room to doubt the plausibility of a means of accurately representing the postmodern: to accurately produce a cognitive map, the Jamesonian subject must be able to escape the impoverished position that produces the conspiracy theory.[36] Essentially, Mason asks, if the totality of the conspiracy is a product of the working of the political unconscious, a projection of the felt but

[33] Jameson, "Cognitive Mapping," 356.
[34] Mark Fenster, *Conspiracy Theories: Secrecy and Power in American Culture*, 2nd edition, Minneapolis: University of Minnesota Press, 2008.
[35] Fenster, *Conspiracy Theories*, 128.
[36] Fran Mason, "'A Poor Person's Cognitive Mapping,'" in *Conspiracy Nation: The Politics of Paranoia in Postwar America*, ed. Peter Knight, 40-56 (New York: New York University Press: 2002).

un-representable inter-relatedness of globalized postmodernity, then to what extent can an enriched, whole, cognitive map be produced? Mason's depiction of conspiracy is clearly concerned with the same questions of agency as Jameson, Fenster, Dean, and Brown but where they describe a crisis she suggests that conspiracy typifies an increasingly normative position: "The conspiratorial subject represents a postmodern self-incapable of critical distance, the result of which is a self-reflexive subjectivity that is itself a reproduction of postmodern culture. […] Conspiratorial subjectivity is a paradigm of a scattered postmodern and global subjectivity."[37] Paradigmatic of an epoch characterized by shifting boundaries, inequitable balances of power, and subjectivities that are simultaneously radically expanded but which experience a diminishment of agency, conspiracy theory is, for Mason, a narrative form that exemplifies a discursive tendency away from traditional markers of subjectivity. We might consider here the literary theorist Raymond Williams' observations on "structures of feeling": patterns of textual activity – tropes, figures, genres – that signal protean responses to shifts in patterns of social experience; in other words, they delimit emerging social forms that are yet to coalesce into more formal and overt structures.[38] So, where Mason describes the narrativization of an emergent social, cultural, and political paradigm, it is possible to consider this in the form suggested by Williams.

VII. From Conspiracy Theory to Conspirituality

The context of post-Gagarin religiosity described above provides a useful starting point for understanding the paradigmatic uncertainty – future shocked and culture lagged – of recent conspiracy theories. The interweaving of narratives concerned with bodies, limits, science, domination, loss of representation, political cynicism, hidden elites, secret knowledge, concealed technologies, alien agendas, and a crisis of subjectivity and agency are the tropes and "semantic figures" that characterize the conspiratorial milieu but they are also present in an increasing number of emergent spiritualities. Ward and Voas have characterized this convergence of conspiracy theory and spirituality as "conspirituality."[39]

Conspirituality is a fitting descriptor of the spiritualized post-2002 online communities that Ward and Voas describe. The defining characteristics reflect the two discursive tendencies: from conspiracy theory comes a belief in a malevolent "shadow government" that manipulates mass populations for hidden, and frequently apocalyptic, ends; and from New Age spirituality is the belief that personal transformation has the capacity to transform the world and a critical mass of transformed individuals have the collective power to overcome the negativity of the evil machinations of the shadow government.[40] In this context they refer to the centrality of the idea of "paradigm shift" in the rhetoric of conspirituality and the behaviors and values that typify it:

[37] Fran Mason, "'A Poor Person's Cognitive Mapping,'" 54.
[38] Raymond Williams, *Marxism and Literature*, Oxford: Oxford University Press, 1977, 131–135.
[39] Charlotte Ward and David Voas, "The Emergence of Conspirituality," *Journal of Contemporary Religion,* 26 no.1 (2011): 103-121.
[40] Ward and Voas, "The Emergence of Conspirituality."

> We [Ward and Voas] argue that conspirituality is a politico-spiritual philosophy based on two core convictions, the first traditional to conspiracy theory, the second rooted in the New Age:
>
> > (1) A secret group covertly controls, or is trying to control, the political and social order (Fenster).
> >
> > (2) Humanity is undergoing a 'paradigm shift' in consciousness, or awareness, so solutions to (1) lie in acting in accordance with an awakened 'new paradigm' worldview.[41]

Again, Williams' figure of a structure of feeling is fitting here and the repeated refrain of a new paradigm, or structure of experience, underlines the purposive attempt to reimagine social relations in a way that reinserts the subject into history with purpose and the agency to realize that purpose. Moreover, in the context under discussion here – emergent post-Gagarin UFO NRMs – these two "core convictions" are consistent elements in conspiritual beliefs that incorporate alien lifeforms and alien worlds. Ward and Voas are attendant to the inchoate and nebulous variety of standpoints incorporated in conspirituality. The groups being described here as "post-Gagarin NRMs" are diverse and their beliefs are contradictory but those beliefs share certain key themes; not least among those themes is an attempt to provide a space from which a technologically-informed spirituality can confront the complexities of being human in an age of space travel. In so doing they produce an aggregate of exploratory statements that attempt to re-orient humanity in a spaceward direction. It is an aggregation of fear and hope and, markedly, an attempt to reconcile a sense of a discontinuous narrative in which the boundaries of "the human" are undermined. In other contexts, Donna Haraway delineated a similarly fatal trajectory for "the human": "It is certainly true that postmodernist strategies, like my cyborg myth, subvert myriad organic wholes. In short, the certainty of what counts as nature is undermined, probably fatally."[42] The certainty of what constitutes the human – and religious – subject is the basis of the continual reflexive assessment and reappraisal, a reappraisal that continually vacillates between the natural and the technological, the earthbound and the space age. Again, the twin poles of the salvific and cataclysmic are replicated in these oppositions. Lee Quinby recognizes this bifurcation and the liberatory heart of this dialectic - it is the utopian impulse discerned by Jameson, Brown, and Mason: Barasch's upward apocalyptic trajectory:

> Whether salvific or catastrophic, apocalyptic rhetoric about technology is exhilarating and persuasive because it triggers deeply entrenched desires for the millennialist dream: transcendence of human limitations.[43]

The conspiritualist desire for spiritual transformation encapsulates the exhilarating transcendence amid a fear of the future as described by Quinby. At once the cultural lag and future

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[41] Ward and Voas, "The Emergence of Conspirituality," 104.

[42] Donna J. Haraway, *Simians, Cyborgs and Women: The Reinvention of Nature*, London: Routledge 1991, 152-3.

[43] Lee Quinby, *Millennial Seduction: A Skeptic Confronts Apocalyptic Culture*. Ithaca, NY: Cornell University Press: 1999, 127.

shock described by Pop is incorporated into a meaningful narrative[44] and it is this narrativization of an unmapped social territory that locates conspirituality in the politicized sphere described by Jameson, Fenster, Mason, and Brown.

VIII. The Galactic Conspiracy

Typical of this second wave of conspiritualism is Laura Magdalene Eisenhower. Much like, say, David Icke, she speaks at public events within the cultic milieu while also giving solo lectures across much of the English-speaking world. Her website describes her as an

> Intuitive Astrologist, Global Alchemist, Cosmic Mythologist and [she] is the great-grand-daughter of Dwight David Eisenhower. She is on a profound mission to reveal our true origins connected with the 'Magdalene' and 'Gaia-Sophia' energies of love and wisdom and works to liberate us from the Military Industrial Complex, the Archonic systems and false power structures.[45]

She is emblematic of this spiritualized, spaceward looking conspiracy theory in which Barasch's vertical movement is simultaneously upward (salvation) and outward (of the world) but also downward (cataclysmic) and inward (the spiritual domain of self-transformation). While sharing the interior quest for enlightenment with earlier New Age inflected UFO NRMs such as the Aetherians, what was a quest to ascend the hidden dimensions of being becomes here a battle for survival and self-determination against the totalizing and dehumanizing efforts of machinic aliens, and to define and characterize enchanted space while saving the Earth. The relocation of this conflict away from the material to the spiritual represents a shifting terrain of agency confirming Eisenhower's narrative as conspiritual rather than straightforwardly conspiratorial. Typical of the epistemic nebulosity identified by Ward and Voas, Eisenhower is highly syncretic in the elements from which she combines her belief system. Illustrative is the following conceptually-loaded paragraph from an autobiographical position statement entitled, "2012 and the Ancient Game: Venus–Sophia and Recruitment to Mars."[46] Here alone she refers to:

> Post-Gagarin readings of the Nag Hammadi Gnostic scriptures; feminist spirituality; ecologically aligned spirituality; millennialism; conspiracy by a global elite; the current and ongoing colonization of Mars; multi-dimensional being; "global transformation"; secret technologies; psychic readings; 2012 as a "shift date"; a shared human destiny as "galactic voyagers," in touch with currently hidden potential; "the false-matrix"; stargates; Goddess

[44] Pop, "Space Exploration and Folk Beliefs on Climate Change."
[45] Laura Magdalene Eisenhower, "About," Cosmic Gaia: Into the World Soul, last modified February 5, 2015. http://cosmicgaia2012.com/about.html [Site may not be available].
[46] Laura M. Eisenhower, '2012 and the Ancient Game: Venus–Sophia and Recruitment to Mars,' Cosmic Gaia: restoring the balance between humanity and nature, last modified September 6, 2014. https://sites.google.com/site/lauramagdalene/home/2012-and-the-ancient-game.

archetypes “Hathor, Isis, Inanna, Kali, Persephone, Magdalene, Guinevere, Morgaine, Ariadne”; alien abduction; predestination; the secret colonization of Mars; Templars; hybrid alien-human lifeforms; the Anunnaki and the planet Niburu.

This list is indicative rather than exhaustive. The battlegrounds and symbolic structures are multiple and complex but the “negative agenda” she alludes to as the enemy of awareness and human fulfillment is repeatedly characterized as patriarchal, aligned with the Archonic entities, and responsible for the destruction of the environment and a forced colonization of Mars. The destruction of the Earth is a planned event designed to eradicate the creativity and female-oriented energies of the divine feminine. The incorporation of a feminist agenda here is novel but not original (one might think of Zsuzsanna Budapest’s Dianic Wicca or Starhawk’s ecological feminist paganism) but the threatening space technologies conform to post-Gagarin UFO conspirituality.

Again, attention is focused on the threat and danger of technologically enabled journeys along the “celestial path” while the redemptive possibility of spiritual transcendence is offered as a counter-measure. These spiritualties seem to revolve around science and technology but are never quite able to escape their orbit. Writing about Heaven’s Gate in *Prophets and Protons: New Religious Movements and Science in Late Twentieth-Century America*, Benjamin Zeller draws attention to the central role that technology played in their development.[47] He finds in Heaven’s Gate a tendency common to UFO religions – for the groups to characterize their beliefs as either non-religious or to see themselves as being a new stage in the development of human thought that transcends what is for them the false dichotomy between science and religion. What is of relevance here is the emergence of religious expressions that not only look beyond the Earth but which also have a strongly materialist orientation – those that would seek to place science and religion on the same continuum. I argue that it is here, in the commingling of religious and secular thought primarily focused on transformation of humanity in the context of an enchanted and populous cosmos that the potential for these religions to overlap with conspiracy theory becomes most profoundly fecund. The post-Gagarin religions become embroiled with the conspiratorial elements of the cultic milieu at the point at which there is the attempt to construct an account of reality that can – within the terms stipulated by the beliefs themselves – be tested as opposed to being a question of faith. Certainly, this changes the terms of the debate around any such religion’s veracity; where they are disproven by science the response is that the failure to detect, say, the presence of alternate levels of existence on planets within the solar system is a limitation of our current equipment, as the Aetherians would have it. Or, more pertinently, in the case of Laura Eisenhower it can be suggested that evidence of the planned evacuation of Earth by the “Global Elite” is being suppressed and that its revelation would amount to eschatological fulfillment – the whole syncretic mélange of beliefs would be confirmed by this affirmation of this keystone. Thus, the status of knowledge has become a vital part of the conspiratualist world picture. Rather than science being an opposing form of knowledge it can be an ally that is waiting to fully realize its potential. It is in this contestation over objective reality that situates the UFO religions within a shared discursive space with conspiracy theorists. To borrow from Barkun’s schema, the UFO religions derive their discursive status in relation to, and tandem with, other forms of stigmatized knowledge, namely

[47] Benjamin E. Zeller, *Prophets and Protons: New Religious Movements and Science in Late Twentieth-Century America*, New York and London: New York University Press, 2010.

suppressed knowledge and rejected knowledge.[48] Indeed, Barkun uses examples of UFO conspiracy theories to illustrate these two sub-categories. The more organized and structured UFO religions provide narratives that are sufficiently internally consistent for them to eschew external sources for further support or proof (Raël, for instance, dismisses other claims of human-alien contact: "there is [sic] no other Messengers and any group claiming such things are just imposters."[49] In contrast, highly syncretic emergent religious forms that lack the structured beliefs that foundational texts provide will often align themselves with well-established truth-claims from within the conspiratorial milieu. For both structured and unstructured UFO religions, the stakes are the same: the stigmatization of their epistemic foundations calls into question their belief system as a whole.

IX. Conclusion

Nonetheless, the treatment of this stigmatized knowledge is not consistently the ridicule and rejection that Barkun's position would suggest. Recent coverage of both Laura Eisenhower and the Raëlian movement has been largely sympathetic. Both have been covered by news outlets: *The Examiner* (US, Eisenhower) and *The Daily Mail* (UK, Raëlians). Neither are looked to as mainstream news sources but both tend toward a normative, culturally conservative line, so it is perhaps surprising that they both show little hostility toward Eisenhower and the Raëlians. *The Daily Mail* ran a predictably sensationalist headline ("'We're creating an embassy to welcome the Elohim back to Earth!' Inside the wacky world of the Raëlians - a cult who think humans are descended from ALIENS") but provided a relatively open platform to Glenn Carter, head of UK Raëlian operations.[50] *The Daily Mail* has since drawn on Raëlian spokespeople to comment on stories reporting purported UFO sightings.[51] *The Examiner* was even more sympathetic to Laura Eisenhower and ran a story titled, "Whistleblower Laura Magdalene Eisenhower, Ike's great-granddaughter, outs secret Mars colony project" which interviewed Eisenhower and provided links to recorded web radio broadcasts and her webpages.[52] Although of little consequence in the wider public sphere, these stories show a greater tolerance for UFO spiritualities within the cultural mainstream than might be otherwise expected. The mass media is here not generative of stigma in the way that Barkun suggests. While the publications do not embrace Eisenhower's position, nor that of the Raëlians, they are provided space amid celebrity gossip and reactionary editorials. They are presented as part of the fabric of current cultural expression and so it is argued here that this is because of the inherent tendency for new semantic figures – be they evidenced or fantasy – to convey the protean fears and hopes of an age: typifying Williams' structures of feeling and Jameson's impoverished cognitive maps. UFO-centered conspiritualities are part of a discursive field that incorporates the New Age and its antecedents, Gagarin and conspiracy theories; indeed, UFO

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48 Michael Barkun, *A Culture of Conspiracy: Apocalyptic Visions in Contemporary America*, 2nd Edition, Berkeley: University of California Press, 2006.
49 Raël, Facebook message to the author.
50 Ruth Styles, "'We're creating an embassy to welcome the Elohim back to Earth!'," *The Daily Mail*, May 9, 2014. http://dailym.ai/2deGwlU.
51 F For instance, see Keiligh Baker, "What is this mysterious purple disc flying over Peru? TV host interrupts interview so cameras can focus on 'UFO' hovering over city," *The Daily Mail*, February 25, 2015. http://dailym.ai/2dM80mI.
52 Alfred Lambremont Webre, "Whistleblower Laura Magdalene Eisenhower, Ike's great-granddaughter, outs secret Mars colony project," *The Examiner*, February 10, 2010. http://www.bibliotecapleyades.net/marte/esp_marte_59.htm.

conspiritualities are vital to providing the shade and nuance through which perceptions of the impact on human subjects and agency by our first, faltering steps along the celestial path can be explored and integrated into a hesitant culture overwhelmed by the cosmic scale of our emergent space age subjectivities. Certainly, these perspectives described are not general or mainstream. These are minority beliefs. The following table shows web traffic to the homepages of Laura Eisenhower, the Aetherius Society, and the Raëlian Movement. Superficially, the 83,000 visitors to the Aetherius webpage represent a considerable number of visitors but, by the same measures, the most popular religious websites reveal these to be relatively low visitor numbers with the visitors staying for less time and viewing fewer pages.[53]

Table 1: Traffic to Conspiritual Websites

	Visits per month (September 2016)	Length of visit	Pages viewed	Origin of visitors
Cosmic Gaia (Eisenhower)	3,900	1:57	1.54	US (35%) New Zealand (23%) Canada (17%) +7
Aetherius Society	83,200	1:14	1.58	US (49%), UK (9%) India (7%) +36
Raël	46,700	1:47	2.38	France (13%) US (11%) Turkey (9%) +35

By comparison, the most frequently visited religious websites, the official Jehovah's Witnesses website, received 73.9 million monthly visitors in the same period with visitors looking at, on average, six pages for just over a seven minutes period. Other popular religious websites report similar figures. Not only do the cosmic NRMs not attract comparable numbers but they also do not achieve the same level of engagement. Nonetheless, these groups represent an emerging tendency within Western religious life. They also demonstrate a notable resilience. The Aetherius Society is unusual among NRMs for surviving and thriving after the death of its founder, George King. Laura Magdalene Eisenhower's number of web visitors is notably lower than the more established, institutionally grounded religious movements, but she has been discussed as an exemplar of the multitudinous *light workers* who incorporate conspiritual motifs in their practice and public statements. Her exposure in the mainstream news media, in addition to her familial status in the US, makes Eisenhower notable, but her beliefs are not unusual within the milieu in which she operates. A list of comparable figures might include (but should not be limited to) Steve and Barbara Rother, Ivo A. Benda/Universe People, Ascension Research Center, Church of the Cosmos, Sandy Stevenson, Cameron Day, and Greg Prescott and the in5D media initiative. The examples

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[53] Although crude, these web statistics allow a comparison of figures gained through a consistent (if undisclosed) methodology. Webstats gained from <https://www.similarweb.com> on October 14, 2016.

discussed in this article exemplify an aggregated inclination toward a cosmically-informed spiritual outlook. The key point is that while this article does not purport to identify a general trend within human religious thought and recognizes the limited spread of the "cosmic NRMs," it is intended to demonstrate that the space age has effected change within human religious thought. It must be acknowledged, then, that this phenomenon is marginal, but this is a change that is sufficiently resonant with current sensibilities to attract believers around the world and wider coverage in the mass media.

BOOK REVIEW

Peter Dickens and James S. Ormrod, eds.
The Palgrave Handbook of Society, Culture and Outer Space
London: Palgrave Macmillan
480 pp
Price: $216.00 (Hardcover)
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The Palgrave Handbook of Society, Culture and Outer Space challenges what it views as prevailing idealistic and simplistic notions of "outer space," explores how a once vibrant and promising frontier has been prematurely tainted and co-opted by Earth's ingrained power conflicts, bureaucracies, and hegemonic influences, and offers some glimmers of hope for a more authentic future for Earth's relationship with space. Updating and expanding on the themes of their earlier work, *Cosmic Society: Towards a Sociology of the Universe* (2007), editors Peter Dickens and James S. Ormrod approach this current anthology as an opportunity to explore not only how Earth's class, gender, and race struggles (to name a few) create our ideas about outer space, but equally powerful, how our hegemonic constructs of outer space reciprocally impact the terrestrial "social order" (2). After a short and messy romp through the chronological timeline of human space travel, Dickens and Ormrod quickly home in on Henri Lefebvre's Spatial Triad of the representations and production of space and meaning (at its most simplistic, understood as the creation of mental, physical, and social spaces) as a "narrating" principle – extending it beyond Lefebvre's paradigm to include "outer" space and aligning individual chapters accordingly throughout the anthology (19).

While many of the chapters are planted firmly within well-worn Marxist interpretations of power dynamics, the entries overall are both thought-provoking in their depth and imaginative in their approach; notable examples include Jason Beery's grounding essay on terrestrial geographies and how the "… mapping, naming, and framing …" of outer space have more to do with Earth than the heavens (62); Peter Dickens' astute diagnosis of the "commodification" of the cosmos evolving into a nascent "cosmic capitalism" (84-85); Nayef R.F. Al-Rodhan's impassioned advocacy of outer space as a "global commons" (160); Christy Collis' comprehensive analysis of the patchwork quilt of legal protections and designations determining who "owns" outer space; Sean Redmond's thoughtful examination of how outer space films manifest – implicitly and explicitly – terrestrial constructs of white privilege; and Nicola Triscott's skillful revealing of the creative and critical role that contemporary art has played in the public imaginings of outer space.

Where the anthology most excels is at exposing the contradictions in the self-reinforcing narratives producing our idealized concept of outer space: the innate drive for exploration and discovery, the wilderness frontier, the experience of wonder and purpose (human and divine), and the guttural power of both creation myths and scientific breakthroughs. It is in revealing the uglier side of those narratives (concentration of capital and power, economic inequality, privacy intrusion, and the commanding power of the military-industrial complex) that the anthology most reveals its Marxist ideological bent.

In hindsight, however, perhaps the anthology is trying to do too much: extending Lefebvre's foundational theory of the production of human spaces to outer space; digesting an extensive and eclectic array of space-related literature across the spectrum of the humanities, arts, and the social sciences; producing a Marxist-girded narrative on terrestrial power dynamics transposed to the cosmos; critiquing humanity's paradoxically quixotic, yet often self-defeating ambitions in outer space; topped off with the final fiat that the "… production of outer space cannot be understood as anything but central to how terrestrial social life is lived" (462). That is a hefty intellectual load for any single volume to bear, and the strain at times is apparent. Further, the very interconnectedness of the individual chapters – akin to the interwoven and overlapping nature of Lefebvre's own triad of spaces – often defies the editors' efforts to corral them into a neatly tripartite structure. Notably, the anthology's Conclusion launches into a protracted critique of utopias and a new pondering of outer space as a potential *heterotopia* – an interesting tangent that, along with the book *in toto*, offers a hopeful "counter-hegemonic" narrative for outer space, but one which merited its own chapter in the body of the work instead of leaving the volume without a satisfying final essay (461). Dickens and Ormrod's confession that "the strength of this volume is paradoxically revealed through the many ways in which its structuring fails" is an honest admission, but it begs the question of whether the editors sometimes favored structure over message (23).

The weaknesses of the anthology, however, fade in the fervor of its overarching takeaway that outer space is a vibrant social, cultural, economic, and political construct that warrants urgent and thoughtful discussion and debate, not just by scientists and politicians, but also by social scientists, humanists, artists, and an engaged general public. In a turn of phrase that could well serve as both a fitting introductory and concluding sentiment to the entire anthology, Dickens and Ormrod remind us that, "Outer space is now, as much as ever, a confused space" (4). To its credit, this complex, sometimes flawed and unwieldy, but ultimately, intricately interdisciplinary anthology succeeds in forwarding that discussion and offering some needed clarity to the confusion.

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Astrosociology Research Institute

ABOUT THE ASTROSOCIOLOGY RESEARCH INSTITUTE

The Astrosociology Research Institute (ARI) is a registered 501(c)(3) organization and California nonprofit public benefit educational corporation dedicated to the development of astrosociology as a multidisciplinary academic field consisting of the social and behavioral sciences, humanities, and the arts. Astrosociology is defined as the study of astrosocial phenomena (i.e., social, cultural, and behavioral patterns related to outer space). ARI seeks to build and foster cutting-edge astrosociological research, support the development of astrosociology into academia, and provide students interested in astrosociology with opportunities to contribute to the study of astrosocial phenomena. ARI's development of astrosociology serves to unite interested theoreticians, researchers, scholars, and students together so they may more easily collaborate on space issues from a broad social-scientific perspective that is, a concentration on the human dimension. Moreover, the Astrosociology Research Institute is not a space advocacy group. Rather, ARI dedicates itself to conducting science and to helping others do the same so that we may all construct a coherent astrosociological body of knowledge and related literature, and place the field of astrosociology into academia as a permanent fixture.

INSTRUCTIONS FOR AUTHORS

The Journal of Astrosociology is the first academic journal dedicated to the study of the two-way relationship between human society and the outer space environment. The journal seeks to promote research into *astrosocial phenomena*, i.e., social, cultural, and behavioral patterns related to outer space. The journal seeks to publish inter- and multi-disciplinary research, as well as essays that fall into the sphere of astrosociology (*see* **Suggested Topics**). The journal also accepts book reviews that relate to astrosociological topics as well as space and society issues.

Submission of Manuscripts

Authors are requested to email their manuscripts to the Editor-in-Chief at **joa@astrosociology.org**. Manuscripts must be drafted using a MS Word readable format, e.g., .doc or .docx. Authors are responsible for ensuring that their manuscripts conform to the journal's formatting and citation requirements. *Please do not send PDF copies for review or previously published manuscripts*. However, the journal will consider publishing conference papers provided the Author has retained sole copyright in the manuscript. It is the policy of *The Journal of Astrosociology* not to publish previous works, but the Editor-in-Chief retains the discretion to make reasoned exceptions in consultation with copyright holders. If an Author desires to publish a conference paper, please acknowledge in the correspondence with the Editor-in-Chief that the paper has been previously published and state the person or institution that retains copyright. In addition, if the manuscript is under consideration with another publication or journal, please inform the Editor-in-Chief when submitting the manuscript. Failure to notify the Editor-in-Chief of a manuscript's previous publication or consideration by another journal or copyright status shall be considered a potential breach of contract with the Astrosociology Research Institute and may result in denial of publication.

When submitting your manuscript, please provide your name, affiliation, contact address, phone number, and names and emails of all co-Authors. If material is translated from another language into English, please provide the name of the translator. Please note that *The Journal of Astrosociology* does not provide translation services, but is willing to assist Authors who wish to publish in a language other than English.

Student Submissions

Students currently enrolled in a full- or part-time program of study can be published with the journal provided a submitted manuscript meets editorial standards. *The Journal of Astrosociology* is dedicated to assisting students who wish to engage in astrosociological theory and research. To that end, the journal will dedicate exclusive space in the journal to students. Students are encouraged to publish with the journal and the editorial staff will assist students to the greatest extent possible to get their work published. The journal will accept any original research, essay, or class paper for publication. Students are also encouraged to submit book reviews. If you are a student and wish to publish with the journal, please contact the Editor-in-Chief directly at **joa@astrosociology.org**. Include in the subject line of the email "Student Submission" and include in the body of the email your abstract, contact info, program of study, graduation year, and attach your manuscript as a Microsoft Word readable document.

Editorial Procedures

The Editor-in-Chief makes the final decision on publication of submitted manuscripts. To determine whether a submitted manuscript meets the standards for publication, each manuscript (except **book reviews**) undergoes a blind peer review conducted by members of the Editorial Board. Members of the Editorial Board shall conduct an objective and anonymous review of manuscripts submitted to them by the Editor-in-Chief. Once the Editorial Board provides a recommendation to the Editor-in-Chief regarding publication, a manuscript is managed by the journal's editorial staff. The editorial staff will review each manuscript to ensure that it meets the journal's editorial standards, as well as the relevant aims and goals of *The Journal of Astrosociology*. The Editorial Board and editorial staff will review a manuscript for analytical rigor, spelling, grammar, style, length, and relevance to the field of astrosociology. The Editor-in-Chief, upon recommendation from the editorial staff, may require an Author to make reasonable changes and corrections as appropriate. An Author's failure to agree to reasonable changes could result in delayed publication. All disputes between an Author and the editorial staff shall be resolved by the Editor-in-Chief and conducted in good faith.

Once the Editorial Board has provided a recommendation for publication, the Editor-in-Chief will designate the manuscript provisionally accepted. At that time, the Editor-in-Chief will require the Author to sign, date, and return a license to publish with *The Journal of Astrosociology*. The license to publish forms a contractual relationship between the Astrosociology Research Institute and the Author that binds the Author to publication with the journal. Once the Editor-in-Chief receives an Author's license to publish, the editorial staff will begin the editing process and periodically keep the Author informed of the status of the manuscript and citation review. Following the editorial review, the Editor-in-Chief will transmit the final edited copy back to the Author for approval prior to publication. Publication of the final reviewed manuscript will occur after Author approval. However, the Editor-in-Chief reserves the right to withhold publication for suspicion of plagiarism, mischaracterization, or misrepresentation of material, unethical behavior by the Author, use of potentially libelous statements, substandard grammar and analytical rigor, failure to obtain a license or waiver to publish copyrighted material, or discovery of past publication. In addition, the Editor-in-Chief also reserves the right to hold a manuscript over for publication in a subsequent issue. However, the Editor-in-Chief will first consult with an Author to ensure the decision does not prejudice the Author.

Submission Types and Standards

The Journal of Astrosociology accepts three types of manuscripts: **articles**, **essays**, and **book reviews**. Criteria for each are as follows:

- **Articles** are submissions between approximately ten thousand (10,000) and twenty thousand (20,000) words of original research
- **Essays** are submissions generally under ten thousand (10,000) words that advocate a viewpoint or normative position
- **Book Reviews** may not exceed three thousand (3,000) words consisting of an objective critique of another Author's work.

An Author may seek a waiver on a manuscript's word limit upon a timely petition to the Editor-in-Chief. The Editor-in-Chief will weigh the recommendation of the editorial staff against the Author's argument for the page limit waiver.

Formatting

Articles, **essays**, and **book reviews** must be formatted according to the journal's standards. A person who submits a manuscript to the journal must ensure that it conforms to **general formatting** standards and **specific formatting** standards for their submission type. Editors will not retype manuscripts that do not conform to the journal's standards. Failure to properly format a manuscript using the journal's standards will result in a publication delay and/or withholding from publication until the manuscript conforms to formatting requirements.

General formatting requirements include:

- Double Spacing
- Text in 12-point Calibri font
- One-inch (1"/2.5 cm) margins
- Submission Title, Name(s) of Author(s), and Affiliation(s) of the Author(s)
- Titled section breaks including an introduction and conclusion(s)/recommendation(s) sections. For each new section, provide a title for the section and use roman numerals (I, II, III, IV, …) in consecutive order starting at "I" for the introduction section
- A zero footnote with contact information of the Author(s) such as email or institutional address and, if desired, acknowledgements
- Every page numbered at the top, right-hand corner starting with the number "1" and numbered consecutively
- Footnotes (*see* **Publication Integrity and Citations**).

Specific formatting requirements include:

- **Articles** and **Essays**
    - An abstract limited to no more than three hundred (300) words
    - If applicable, Appendices ordered using Arabic numerals (1, 2, 3, …)
    - If applicable, figures (*see* **Figure Formatting**) with appropriate labels or captions
- **Book Reviews**
    - Name of the Book Reviewed
    - Where applicable, Name(s) of Book Author(s) or Editor(s), and/or Translator(s)
    - Name of Publisher and Year of Publication
    - Number of Book Pages
    - Retail Price of Book

Figure Formatting

An Author may include a figure, e.g., picture, graph, table, map, diagram, and/or chart, which supports any premise or thesis, illustrates an example, or provides essential data in the manuscript. If an Author embeds a figure into his/her manuscript, s/he must attach a standalone copy of each properly labeled figure along with the manuscript when submitting to the Editor-in-Chief for publication consideration. Within the manuscript, each figure must be clearly labeled, consecutively numbered starting with the number one (1), and given an appropriate caption that succinctly describes the figure and its relevance to the material presented in the manuscript. Finally, each figure must appear on the page that first references the figure along with a proper corresponding reference in the manuscript text.

Any figure considered an image, e.g., a picture, map, drawing, or diagram, should be formatted as an uncompressed *.jpeg* file. All other figures should be formatted as a separate Microsoft Word, Microsoft Excel, or Rich Text Format file. Figures must not be tinted or photo-shopped from its original format. All digital files should be in *300 dpi or greater* resolution and sized no larger than *4 x 7 inches*.

All figures must either be the original work of the Author or an Author must obtain a license or waiver to publish copyrighted material or must notify the Editor-in-Chief that the figure is fair use material (*see* **Legal Notice and Policy**).

Publication Integrity and Citations

The Journal of Astrosociology is dedicated to publishing high-quality, original manuscripts that cover theory, research, literature review, or normative essay. To that end, manuscripts submitted for publication undergo a blind peer-review conducted by preeminent and scholarly members of the Editorial Board. All Authors who submit a manuscript for publication agree to originality reviews so that the journal can maintain its status as a leader and publisher of original astrosociological-based research and discourse. Any Author found in violation of this covenant will have his/her manuscript removed from publication. An Author found in violation of this covenant through clear and convincing evidence will be prevented from future publication in the journal. The Editor-in-Chief also reserves the right to publish a notice regarding an Author's violation of this covenant in a subsequent issue of the journal.

Because of the inter- and multi-disciplinary nature of the journal, an Author is permitted to select *one* method of citation from the list below that covers most scholarly fields. The journal will accept the following citation systems for use in a manuscript:

- The Bluebook
- Association of Legal Writing Directors (ALWD)
- Canadian Guide to Uniform Legal Citation
- Modern Language Association (MLA)
- American Psychological Association (APA)
- The Chicago Manual of Style
- Turabian Style
- American Political Science Association
- American Anthropological Association
- American Sociological Association
- American Institute of Physics

All references should be in footnote format and numbered consecutively with corresponding superscripts in the body of the manuscript, except where provided as part of the rules of a particular citation system (e.g., embedded citations in APA and ASA). Do not use endnotes, scientific notation, or bibliographical references as citations. *Use only one of the above citation methods for references.*

SUGGESTED TOPICS

Acceptable Topics for The Journal of Astrosociology

The Journal of Astrosociology is the official journal of the Astrosociology Research Institute and the primary resource for astrosociological theory and research. The unique approach expected for contributions to this journal involves a specific reference to *astrosocial phenomena*. It is this focus on the human dimension of space, i.e., the relationship between space and humanity, which sets astrosociology apart from other approaches. Contributors are asked to incorporate the field of astrosociology into their research and focus in some recognizable fashion on *astrosocial phenomena*. To assist Authors, the Astrosociological Research Institute offers free access to astrosociological resources in our Virtual Library:

http://astrosociology.org/vlibrary.html#VL_Newsletter.

The major acceptable topics, discussions, and related questions to be addressed for journal manuscripts and other submissions are listed below. The questions and statements below are only examples to stimulate ideas among our potential contributors and many aspects of each can be combined into a single approach or discussion.

1) Definition of Astrosociology

Discussion: The baseline definition of astrosociology – that is, the scientific study of *astrosocial phenomena*, or the social, cultural, and behavioral patterns related to outer space – serves as a fundamental starting point. Defining the human dimension of space exploration, settlement, and resource exploitation, which involves the two-way relationship between humankind and space, is a critical area of scientific investigation. Suggested research questions/issues include:

- What does the astrosociological approach, based on the definition above, contribute to traditional approaches in the space community?
- How does the approach of astrosociology as a multidisciplinary academic field affect the development of the definition and the field itself?
- In what ways can the base definition of astrosociology be modified? How would such modifications improve astrosociological investigation?

2) Astrosociological Education

Discussion: The various issues covering astrosociology in the classroom are of great importance to the development of the field. The educational process is critical for informing professionals in the space community as well as younger students about astrosociological issues and how the social sciences can provide original contributions to human space exploration and related substantive areas. Studies that cover the impact of space in the social and behavioral sciences, humanities, and the arts in the classroom are of significant interest for present and future human society. Alternatively, non-classroom based outreach is also an important method to help educate and is of particular interest to the journal. Suggested research questions/issues include:

- What are the various possible educational models? How do they work, and what are their benefits and disadvantages?
- What are some ideas regarding a workshop for existing professionals and the ramifications of developing an astrosociological community?
- Why is integrating astrosociology into existing programs and courses as an intermediate goal a cornerstone of the development process?
- What are the potential student roles in astrosociology education and the field development process?
- How might one establish astrosociology courses, programs, curricula, and departments, including actual efforts and plans for implementation?
- How might one recruit high school and college students to pursue astrosociology?
- What types of methods do/can educators use or have used that incorporate(s) STEM education with the social sciences? How important is it to teach both aspects to students?

3) Theoretical Astrosociology

Discussion: Like any academic field, astrosociology progresses through the interaction between theory and research. The development of astrosociology requires the construction and sharing (for testing) of conceptualizations that focus on *astrosocial phenomena*. Suggested research questions/issues include:

- What are the epistemological limitations of astrosociology?
- How can the astrosociological paradigm be modified to better reflect observations of *astrosocial phenomena*?
- What types of theoretical model(s) and/or hypotheses characterize various types of *astrosocial phenomena*?
- What are the connections between the astrosocial sector, which includes societal elements that involve *astrosocial phenomena*, and the non-astrosocial sector, e.g., what are the connections between NASA and politics?
- How do various facets of *astrosocial phenomena* affect societies? What is their importance to cultural and social change?
- How may space exploration analogs provide new insights and avenues for future research endeavors?
- What literature already exists that addresses areas of astrosociological theory?
- What are some recommendations for future research projects based on theory?

4) Astrosociological Research

Discussion: The testing of hypotheses and theoretical models through various forms of investigation allows for the development of astrosociology. Suggested research questions/issues include:

- What empirical investigations touch on *astrosocial phenomena*, both new research and/or summaries of past investigations?

- What are some tests for astrosociological theoretical models and hypotheses? What modifications could be necessary?
- Review research addressing analogs to space exploration in its various forms, and/or provide new research findings in this area.
- Provide a literature review that summarizes some area of past research that relates in some way to astrosociology.

5) Applied Astrosociology

Discussion: Practical approaches that take advantage of *astrosocial phenomena* for the benefit of societies, communities, and the lives of individuals serve as important contributions of astrosociology. This focus consists of social scientists (including astrosociologists) studying such contributions by others as well as their own participation in such activities. Suggested research questions/issues include:

- What are some examples and/or future possibilities in which the utilization of space assets contributes to the mitigation of social problems on Earth?
- Discuss research that touches on both space and sociocultural and/or psychosocial efforts that contribute to improving social life in terrestrial societies.
- Discuss space spinoffs/technology transfers and their impacts on various social institutions, groups, and categories of individuals.
- How do media and the arts that focus on outer space issues affect human culture? What comparisons can be made cross-culturally that describe how different societies view outer space technologies and activities?

6) Medical Astrosociology

Discussion: Space medicine focuses almost exclusively on the biomedical aspects of space activities such as the effects of microgravity on the human body. Space psychology is also addressed to some extent. However, the social and cultural issues that arise among members of a crew, and in the future among citizens in space ecologies, require a greater focus. These are astrosociological issues that require attention in order to understand the social effects of going into outer space and the ramifications it has on social stability and individual health. Suggested research questions/issues include:

- Discuss various aspects regarding the social, cultural, and behavioral aspects of space medicine.
- What are some of the ethical implications of medical decision-making in space ecologies?
- Discuss the relationship between behavioral health and medical astrosociology.

7) Planetary Defense

Discussion: Planetary defense typically involves the detection and defense against a celestial object impacting humankind's home planet, Earth. These areas of concern are important for astrosociologists. However, the social sciences are also well equipped to study the third component of planetary defense; namely, disaster relief efforts following an asteroid or comet strike. Preparation for the aftermath of a strike would become an issue if defense failed and humankind had time to react before a strike. Suggested research questions/issues include:

- Focus on issues involving detection, defense, and protection of terrestrial life as three different stages or as one united approach.
- Discuss the differences between protecting Earth and protecting human societies and cultures. What are the implications of success, partial success, and failure – and how are these different outcomes defined?
- What level of preparedness is prudent (or too little or too much) to respond to a real threat?
- What actions must be taken, or what actions are necessary, for coping with a strike by asteroid, comet, or other space phenomena? Discuss disaster relief efforts in the aftermath of a strike.
- What types of planning has occurred or should occur to mitigate any potential harm to Earth, human societies, or the human species?

8) <u>SETI and Astrosociology</u>

<u>*Discussion*</u>: SETI, the search for extraterrestrial intelligence, involves listening to radio signals – and more recently other types of emissions and planetary features – from alien civilizations. Astronomers and others seek such signals without any guarantee of success. Social scientists have also played a role in theoretical discussions regarding the potential presence of alien life and the likely responses to the actual discovery of extraterrestrial life. Suggested research questions/issues include:

- What is the cultural impact of the effort itself to detect alien life?
- How does humankind benefit from SETI even before detecting extraterrestrial life?
- Provide analysis and/or profiles of the work of those who carry out the search.
- What are some of the major issues related to constructing and sending messages to potential alien civilizations?
- What are the astrosociological implications of actually detecting alien life?

9) <u>Astrosociological Implications of Astrobiology</u>

<u>*Discussion*</u>**:** Astrobiologists continue to discover new organic molecules in space and various forms of extremophiles in a variety of environments, both natural and human-made. Suggested research questions/issues include:

- Discuss how the search for extraterrestrial life has impacted human society and our species place in the universe.
- How does astrobiological research on Earth affect societies and their various components?
- What is the relationship between astrosociological research and astrobiological theory and research?

- How could astrobiology inform astrosociology as it relates to the rise of social groups among various organisms?

10) Space Law

Discussion: Space law exists to regulate the behavior of social actors, i.e., persons, groups, organizations, and states that operate and conduct activities in outer space. As new space technologies strain the international legal system and the enabling national laws that govern states, we can expect and do see social responses to the use of space technologies. Space technologies bring people closer together and also separate societies who have such space capabilities from those states that do not. Given the social pressures that inherently arise from the technological development to access outer space, space law serves as the regulating mechanism to defuse lawlessness (or anarchy) and provide rules for social actors engaged in space activities. The study of space law, both at the individual, national, and international level, provides a significant backdrop by which to engage in astrosociological research, i.e., at the nexus of law and astrosociology (*see, e.g.,* Hearsey, C.M., *The Nexus Between Law and Astrosociology*, Astropolitics, Vol. 9(1) at 28, 2011). Suggested research questions/issues include:

- What are some of the social and cultural aspects of legal issues related to outer space in terrestrial societies?
- How should states organize law-making and jurisprudential systems for outer space?
- Can or will outer space law be described as a postmodern legal system?
- How will outer space law continue to function or evolve?
- Will extraterrestrial societies, i.e., human societies not on Earth, be held together by a consensus of legal values or by coercion?
- How does outer space law fit into the social construction of law?
- How are rules for outer space connected to the natural law whose content is set by nature and has universal validity? Or is outer space law derived from basic norms?
- Are there aspects of outer space law that constitute peremptory norms? If so, how will that affect social systems that arise beyond Earth?
- How will non-binding rules affect the development of space law going forward? What impact will it have on any aspect of society?

11) Space Policy

Discussion: Policy is a general prerequisite to law and a fundamental aspect of decision-making that encompasses all aspects of social life. As applied to astrosociology, space policy has a wide variety of topics that intersect with the study of astrosocial phenomena. Suggested research questions/issues include:

- What is the status of space exploration in various nations?
- How does governmental space policy affect real efforts in space?
- What impact do private space companies have on governmental space policy?
- Discuss the role of space advocacy groups in affecting space policy.
- How is "New Space" affecting humankind's progress in space?

- Discuss the details of international cooperation in the pursuit of space exploration.
- How do the benefits/costs of space policy (or law) affect segments of human society not engaged in space activities?

12) <u>Space History</u>

<u>*Discussion*</u>: Space has played a significant role in societies throughout history. It is therefore beneficial to study the historical developments in astronomy and space exploration and their social impacts at every level of analysis. Since the history of human and robotic space exploration in the modern era has lasted over fifty years, there have been great achievements, bitter disappointments, tragedies, and some argue lost opportunities. Moreover, the scientific and exploratory aspects considered at the heart of the space exploration have been shaped by politics and other social and cultural forces that resulted often in detrimental outcomes and extraordinary achievements. Furthermore, past human societies have been affected by what happens in outer space and, in some cases, human history has been shaped by celestial events. Suggested research questions/issues include:

- Discuss the space history, or a portion thereof, of societies in any recorded area of study.
- How did space affect ancient societies/pre-historical cultures – e.g., pre-historic Britain, China, Egypt, Africa, Samaria, etc.?
- How have celestial events affected the development of human society? How could expected future events shape the future of human society and what could be the social benefits/costs?
- What impacts did major developments in astronomy, planetary science, rocketry, or space exploration have on societies or groups of people?
- What historical analogs describe current endeavors to venture into outer space?

13) <u>Space Economics</u>

<u>*Discussion*</u>: Generally, economics is the study of how the production, distribution, and consumption of goods and services operate in a society. As technology enables humans to consume space based resources, such activities will significantly affect human society on and off Earth. For Example, satellites are playing a large role in how resources are consumed on Earth. Studying the economic effects of space technologies and activities is therefore an important and underdeveloped topic of inquiry. Suggested research questions/issues include:

- What types of phenomena are observed or could be observed due to human activities in outer space? How do these phenomena affect human society's consumption of space based resources?
- How will the consumption of space based resources change the dynamics of economics on Earth?
- How has technology changed the way resources are used and consumed on Earth? What types of space based assets are important to human society and what are their economic and social benefits/costs?

- Will consuming outer space resources change economic systems? If so, how? If not, why?

14) **Literature and Astrosociology**

Discussion: Oral traditions and literature have played a large role in the development of the social consciousness related to outer space. From stories about gods in the heavens to science fiction about trips to the Moon and Mars, outer space as a subject or backdrop in story-telling has had a significant effect on human society. Suggested research questions/issues include:

- How has space related literature affected human's drive to go into outer space? How has it shaped the social consciousness?
- How does literature create social constructs in human societies to explain our place in the universe?
- What sources of literature have influenced humans to venture into outer space? What themes or lessons are portrayed? What conclusions can society draw from literature?
- How does storytelling through movies or art shape our understanding of space issues?

15) **Space Societies (including Crews, Micro-Societies, Mini-Societies, and Communities)**

Discussion: Human groups living in isolated space ecologies within space habitats – whether on planets, moons, or orbiting a space body – require social-scientific consideration even though very few human beings live in space at one time. Suggested research questions/issues include:

- What are the major issues involving social and cultural aspects of social groups living in non-terrestrial ecosystems/habitats?
- A focus on the definitions of space environments, ecosystems, and space ecologies. How do they differ and how are they related to one another?
- What types of social relationship will emerge between humans that stay on Earth and those who leave Earth to venture out into the Solar System or beyond?

16) **Spacefaring Societies**

Discussion: The future of humankind on Earth is likely to be characterized by a growing influence of space in the lives of citizens as well as social institutions, groups, categories within societies, and international relations among nations. A spacefaring society is one in which the effects of space are omnipresent on a number of different social, cultural, and physical levels. This term refers to an ideal type of society that is impossible to emulate in reality, but represents a potential state that societies can strive toward. Though this possibility can only occur in the distant future, if at all, this topic is open to both theoretical speculation and practical research. Suggested research questions/issues include:

- Discuss studies covering social and cultural change that focus on the possibility of space influencing social groups and social institutions on a greater level.
- Speculate about milestones that may signal movement toward, and/or retreat from, progress toward spacefaring characteristics.

17) Hard Space Sciences and Astrosociology

Discussion: The status of collaboration between the "hard" sciences and "soft" sciences relating to space exploration, settlement, and exploitation of space resources is best characterized as limited, though it is increasing. Suggested research questions/issues include:

- What is the status of collaboration between the "hard" sciences and "soft" sciences relating to space exploration, settlement, and exploitation of space resources?
- What are some examples of, and protocols for, collaborative efforts?
- Describe how the collaboration between the physical and social sciences can result in synergistic breakthroughs impossible by either approach alone.

18) Other Topics

Discussion: The Editor-in-Chief and Editorial Board of *The Journal of Astrosociology* will consider manuscripts covering other areas that address astrosociological issues not covered in this document. Analysis, research, and discussions should involve approaches that address astrosocial issues; that is, social, cultural, and behavioral concepts related to outer space. These issues are common to the social and behavioral sciences, humanities, and the arts. The journal also seeks perspectives from non-social scientists who present credible theories and/or research that ties their work to *astrosocial phenomena*. Failure to address astrosociological topics shall in no way prejudice a potential Author from publishing with the journal, but some topics may be beyond the scope of issues the journal is willing to accept. All questions regarding topics should be addressed to the Editor-in-Chief.

THE JOURNAL OF ASTROSOCIOLOGY
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Editor-in-Chief

Astrosociology Research Institute | *The Journal of Astrosociology*

P.O. Box 1129, Huntington Beach, CA 92647-1129

CALL FOR MANUSCRIPTS: VOLUME 3

The Astrosociology Research Institute proudly announces the call for manuscripts for *The Journal of Astrosociology* (www.astrosociology.org/joa.html). *The Journal of Astrosociology* is the first peer-reviewed, academic journal dedicated to the study of the two-way relationship between human society and the outer space environment. The journal seeks to promote research into astrosocial phenomena, i.e., social, cultural, and behavioral patterns related to outer space. The journal will publish inter- and multi-disciplinary research, as well as essays that fall into the sphere of astrosociology. The journal will also accept book and other media reviews that relate to astrosociological topics.

All manuscripts will go through a blind peer-review process by distinguished members of the Editorial Board. The editorial process will be handled by our competent and knowledgeable editorial staff. Each volume of *The Journal of Astrosociology* will be published online and freely available for download from our Virtual Library, where you will also find resources on astrosociological topics and publications and back issues of our newsletter *Astrosociological Insights* (www.astrosociology.org/vlibrary.html#VL_Newsletter).

Deadline for Manuscripts: February 1, 2018.

The Journal of Astrosociology is the official journal of the Astrosociology Research Institute and the primary resource for astrosociological theory and research. The unique approach expected for contributions to this journal involves a specific reference to astrosocial phenomena. It is this focus on the human dimension of space, the relationship between space and humankind, which sets astrosociology apart from other approaches. Contributors should incorporate the field of astrosociology into their manuscripts and focus on astrosocial phenomena in some recognizable fashion. The major acceptable topics, discussions, and related questions to be addressed for journal manuscripts and other submissions are listed below:

- Definition of Astrosociology
- Astrosociological Education
- Theoretical Astrosociology
- Astrosociological Research
- Applied Astrosociology
- Medical Astrosociology
- Planetary Defense
- SETI and Astrosociology
- Astrosociological Implications of Astrobiology
- Space Law
- Space Policy
- Space History
- Space Economics
- Literature and Astrosociology
- Space Societies (including Crews, Micro-Societies, Mini-Societies, and Communities)
- Spacefaring Societies
- Hard Space Sciences and Astrosociology

For the comprehensive list of suggested topics, visit:
www.astrosociology.org/library/pdf/journal/JOA-Suggested-Author-Topics.pdf.

If interested in submitting a manuscript, please first review the Author Submission Guidelines, which can be found here:
www.astrosociology.org/library/pdf/journal/JOA-Author-Guidelines.pdf.

You may transmit your manuscript to the Editor-in-Chief via email to:
joa@astrosociology.org.

Please feel free to email the Editor-in-Chief with any questions or comments. We hope that you will consider publishing with us soon.

Sincerely,

Prof. Michael Dodge, J.D., LL.M.

Editor-in-Chief, *The Journal of Astrosociology*

Astrosociology Research Institute

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