Space Debris: How Technology as a Self-Determining Entity in Space Impacts Social, Economic, Political and Other Forms of Developing Technology

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring, 2022

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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STS Research Paper

Introduction

Space, the final frontier left for humanity to explore, contains technologies that are viewed as self-determining entities—leaving many to question: how much control does society truly have over technology it produces? The concern over space debris interfering with space operations ranging from commercial satellite networks to political claims of domain ownership is directing more attention to humanity's strained relationship with technology in space (Garcia, 2015). What is space debris and why should one care to investigate its social, economic, and political impacts on modern society? Space debris is divided into two main categories: naturally occurring and artificial, or man-made (ESA, 2021). Artificial space debris, debris that society is directly responsible for producing, results from decommissioned or damaged spacecraft, jettisoned parts, or the intentional use of manmade objects to inflict harm on orbiting spacecraft. This debris presents major concerns over political relations, commercial interests, and how society perceives space technology. The threat posed by space debris on society is best explained by the STS frameworks of technological determinism, co-production, and technological momentum. These frameworks build on one another in the context of supporting the research question explored in this paper. The question that will be explored throughout this paper is how technology as a self-determining entity in space impacts social, economic, political and other forms of developing technology.

Background

Artificial debris and its threat to space assets has become a topic of great concern due to the severity of the issue it poses for existing and future technologies in space. Currently the

Department of Defense (DoD) tracks anywhere from 24,000 to 30,000 objects that are classified as artificial debris (Garcia, 2015). Artificial debris is an issue that has already raised political concerns regarding continued expansion into space. New agencies such as the United States Space Force are being tasked with monitoring this growing area of concern as it also threatens National security (Department of Defense, 2021). Additionally, the Federal Communications Commission (FCC) claims responsibility for new space systems integrating plans for mitigating orbital debris as a part of their respective mission sets (FCC, 2020). The National Aeronautics and Space Administration (NASA) has been forced to implement several policies aligning with the demands of the FCC in order to mitigate space debris stemming from scientific oriented missions (Harrington, n.d.).

Economics is a significant factor in determining who and what gets to go into space. The Organization for Economic Co-operation and Development of space (OECD) is responsible for stimulating economic progress and world trade. The OECD cites impact avoidance and debris mitigation as significant mission costs that mission planners must account for. Societal status and wealth have reignited a space race among the wealthy elite; Jeff Bezos and Elon Musk are relevant figures worth mentioning. Fierce competition among their private corporations in space has led to lawsuits, trivial arguments, and bidding wars over federal funding (Cai, 2021). The masses backing the billionaires and others alike generally support the idea of space exploration but the image of private industries' expansion in space is clearly clouded by underlying competition. Space debris has no limitations on the individuals and entities it impacts. Environmental concerns brought up by the threat of space debris have sparked innovations in debris mitigation technology. Several spacecraft that failed to burn up in the atmosphere upon reentry have caused environmental issues in several communities. Testimonies from Chinese

villagers in the vicinity of space debris impact sites report a disproportionate cancer rate which is likely due to the rocket fuel contained in the debris (Luke, 2021).

Although space debris are not necessarily vital in the sense of having consciousness to make decisions, it is argued that they are self-determining entities through which the domain they congregate and govern. According to the Britannica dictionary, self-determination is defined as "the process by which a group of people, usually possessing a certain degree of national consciousness, form their own state and choose their own government" (Gaur, n.d.). This definition is expanded upon through the analysis of STS frameworks and various methodologies.

STS Framework

The theory of technological determinism states that society is shaped by technology and not the other way around (Hallstrom, 2021). There are some opposing views in Hallstrom's literature as to the extent which society is shaped by technology is questioned. Ultimately, it is determined that society does have some influence over technology's self-determining behavior which is contrary to traditional arguments in technological determinism. For the purposes of this study, technology in the form of unintended artificial debris has taken on a "life of its own" in space and is ultimately independent of the social concerns it raises (Smith, 1994). Capitalist societies, concerned with rapid growth, have seemingly lost control of the technology they have developed for space and as a result, future generations will face the consequences (Adler, 2006). Adler however does provide a counterview in that he argues that the self-determining aspect of technology may not be a negative feature.

Co-production is another framework that serves to define the research question within the field of STS and further analyze the research question. This framework outlines how "scientific ideas and beliefs, and (often) associated technological artifacts, evolve together with the *representations*, *identities*, *discourses*, and *institutions* that give practical effect and meaning to ideas and objects" (Jasanoff, n.d.). In her publication discussing co-production, Jasanoff contrasts a misleading belief that co-production is merely the way society expresses itself with the idea that one must also consider the ethical implications of inventions (Jasanoff, n.d.). Co-production has broader definitions outside the scope of STS research as discussed in the perspective piece by Angela Filipe. In her discussion, Filipe raises the issue that "it is not always evident what counts as co-production." She goes on to cite her definition as "as an exploratory space and a generative process that leads to different, and sometimes unexpected, forms of knowledge, values, and social relations" (Filipe, 2017). Jasanoff and Filipe both present similar definitions of co-production with the minor differences being the focus of what is being studied. For the purposes of answering the research question, Jasanoff's definition will be used as it specifically mentions ideas and objects.

The third STS framework that is discussed is technological momentum. Technological momentum is defined as a "more complex concept than determinism and social construction, technological momentum infers that social development shapes and is shaped by technology" (Hughes, 1984). Popular culture agrees with this relationship between society and technology as seen in the popular television series *Black Mirror.* In the episode "Nosedive" technology is presented as a controlling force that shapes the environment and actions of the protagonist. This framework is used to support the conclusion that space debris, as a form of technology, shapes

society. On the other hand, the framework is also used to call into question the degree to which space debris influences society.

Methodologies

To reiterate, the question that is explored throughout this discussion is how technology, in the form of space debris, as a self-determining entity in space impacts social, economic, political and other forms of developing technology. To investigate this question, several research methods are used: wicked problem framing, policy analysis, and network analysis. Understanding the key issues at hand through wicked problem framing, the policy makeup of regulations regarding space debris mitigation, and the factors at play through network analysis successfully accomplished research goals in this investigation. The scope and relevance of the topic proved to be valuable in the availability of resources used to investigate the research question. Keywords that aided in the research process were “machine learning,” “technology policies,” “space regulations,” “space politics,” and “technological determinism.” These keywords were refined to the scope of the space regulations, policies, and highlighted STS frameworks. The research is organized as follows: an overview of the policies in place and those that are developing using policy analysis, establishing the problem at hand through wicked problem framing, establishing the network of space debris through network analysis, and finally, relating these areas of research back to aforementioned STS frameworks through literature analysis.

The research and discussion presented accomplish the following items using wicked problem framing, network analysis, and policy analysis to connect evidence to STS frameworks and back to the research question. First, the theory of self-determination was used to validate the

proposal that space debris is a complex entity capable of autonomous motivation and thus categorizes as a self-determining entity. Technological determinism was then used to investigate the degree to which space debris impacts society and not the other way around. It was found that space debris has led to innovations in algorithm research and has spawned new fields of science to undergo its removal. Evidence presented agreed with technological determinism favoring soft determinism over hard determinism. It was concluded that space debris, when analyzed in the frame of technological determinism, does influence society but there are likely other factors contributing to sociotechnical evolution. This uncertainty fueled the conversation of the co-production framework. Evidence supporting co-production suggested that scientific ideas and technology within the field of space research and commercialization are dynamic and change relative to the evolutions of space debris. Lastly, investigation of space debris and its relevance to technological momentum found that space debris, with the momentum generated from its increase as a sociotechnical threat, drives sociotechnical change and vice versa.

Self-Determining Entity

To adequately address the research question, the definition of a "self-determining entity" must be fully established. Furthermore, space debris must be classifiable as a self-determining entity in order to validate the research that follows. One such theory that provides insight into what classifies as self-determining is the theory of self-determination. This theory, originating from a background in psychology, can be extrapolated to fit the narrative of space debris existing as a conscious entity capable of making complex decisions having far fetched reactions. According to the theory, motivation is the underlying factor in self-determination. Autonomy, competence, and relatedness all feed into motivation and are interdependent on each other

(University of Rochester Medical Center, n.d.). Wicked problem framing provides a clear understanding of the contradictions that arise when assessing the assignment of space debris to a conscious entity. It also addresses the limitations of the assumptions behind this assignment. Autonomy, or "the feeling one has choice and willingly endorses one's behavior," is arguable as a trait of space debris in that space debris acts on its own accord, free of any interference other than those directly sourced to remove its existence from space. Competence: "the experience of mastery and being effective in one's activity," is also an identifiable trait of space debris in that it exists solely to hinder and interfere with related space endeavors. Lastly, relatedness: "the need to feel connected and belonging with others," is the third identifiable trait of space debris as it relates to its overall motivation (University of Rochester Medical Center, n.d.). It is arguable that space debris possesses a need for connection to other forms of space debris—the network of debris in humanities sphere of influence.

Autonomy, competence, and relatedness all factor into the underlying motivation of space debris. The underlying motivation of space debris is discussed further in this study but for the purposes of establishing the foundation of whether space debris is a self-determining entity, the arguments proposed are sufficient in supporting the claim that it is. According to the University of Rochester, when people, or in this case objects, are autonomously motivated, they are more successful in achieving their goals over time. Autonomous motivation contributes to overall self-determination in the sense that fulfillment, or the achieving of goals necessary for self-determination, is met. Space debris meets all the criteria of the self-determination theory and is evidently an entity, thus the outstanding evidence points to it being a self-determining entity. In the following presentation of research, the underlying motivation of space debris will be analyzed in the context of aforementioned STS frameworks.

Technological Determinism

Technological determinism is a framework capable of supporting the degree to which space debris impacts society and other forms of technology. Due to the unprecedented rise in satellites and the space debris that accompany launches, scientists have realized the necessity of tracking debris with more scrutiny. A few uncontrolled space crashes resulting in hundreds of thousands of new debris could render traditional orbit paths unusable for other spacecraft. According to one article, "researchers are investigating new methods for assessing what is in orbit, so that satellite operators can work more efficiently in ever more crowded space" (Witze, 2018). In the past decade, the call for "traffic cops for space" has led to a growth in space traffic management (Witze, 2018). The field consists of astrodynamicists and space traffic controllers ,similar to air traffic controllers for atmospheric flight. The issue facing this field is the degree to which space debris is accurately pinpointed. In air traffic control, controllers are capable of pinpointing aircraft down to the nearest meter for accuracy purposes. For space traffic control, the location of space debris could vary by several meters to several kilometers which presents major issues for operational satellites. A contributing factor of this issue stems from a lack of an extensive database tracking decommissioned spacecraft.

The issue of space pollution has created so called "space environmentalists" and sparked developments in machine-learning algorithms. Moriba Jah, a self-proclaimed space environmentalist, stated that until space is a safe place to operate, "the space community will continue devolving into a tragedy of the commons, in which all spaceflight operators are polluting a common resource." (Witze, 2018). Jah testified in congress in support of a space regulations bill shifting space debris tracking from a military-only responsibility to a shared commercial initiative.

Through the use of policy analysis, this shift in responsibility highlights the priorities of space faring politics. For one, society values long term establishment of space resources benefitting social aspects of society such as the internet and social media. On the other hand, there is value seen in commercial actors to aid domestic security of space assets. The policies being discussed would ensure all members of society have access to the resources provided by operational spacecraft. On another note, Carolin Frueh, an astrodynamical researcher claims to have experimented with "a machine-learning algorithm that could speed up the process of characterizing items" and plans on discussing this research with officials in the near future. Technology such as the algorithm Frueh is experimenting with indicates a demand fulfilled for space security resulting from the heightened threat of space debris.

On-going debates regarding technological determinism center around the degree to which technology influences society and vice versa. Supporters of this framework are opposed to the idea that social structures and technology co-evolve alongside one another (Adler, 2006). Additionally, supporters may try to argue in favor of "soft" or hard" determinism depending on whichever best fits their narrative in convincing determinism skeptics. Soft determinism essentially states that technology is one of many primary driving factors in social change whereas hard determinism states that technology is the only driving factor (Adler, 2006). The evidence presented is most agreeable with the soft view of determinism. Space debris can't be ruled out as the sole factor driving the necessity for technological and environmental innovations. There are likely underlying actors not mentioned in the evidence which contributes to the overall need for the social changes occurring. On the other hand, critics of technological determinism may argue that space debris as a form of technology and society co-evolve. To elaborate on this point, space debris may initially highlight the need for changes in policy

surrounding the threat of debris, which drives solutions such as space environmentalism, which in turn drives changes in debris as a form of technology. The possibility of co-production can't be ignored and thus it is the focus of the next topic of discussion.

Co-Production

The effect of space debris on policy decisions is analyzed through the scope of co-production. The scientific ideas and beliefs surrounding the threats posed by space debris has evolved over the last four decades, more recently in the past 20 years. According to NASA's report on the *Growth of Orbital Debris*, it was the first organization to develop and structure orbital debris mitigation policies and guidelines in the late 1990s. This shift in devotion of resources on behalf of NASA indicates a slight transition in the organizational behavior of the institution; that is, a shift to conservation. According to the same report, NASA, since 2007, has required rigorous satellite positioning assessments to determine the severity of threats posed by satellites to one another operating in close proximity. This evidence supports the co-production framework in that the scientific ideas held by NASA with regards to space technology of evolved in conjunction with the shifts in institutional values held by the organization. Space debris has evolved from a mere blip on the radars of scientific communities to a legitimate threat worthy of assessing the true practical effect of its existence.

Further supporting the co-production framework, companies such as SpaceX, an organization credited with progressive contributions to society's space endeavors, has faced scrutiny over its recent satellite network. Astronomers in the scientific community expressed concerns over SpaceX's and other space industries disrupting of astronomy research through the development of mega constellations. Satellite constellations positioned in an orbit at or

exceeding 1,200 kilometers would be visible from observatories long after sunset (Foust, 2020). To ease tensions between the space industry and scientists, companies such as SpaceX have agreed to implement technologies such as "DarkSat" and VisorSat," which reduce the amount of light reflected from satellite surfaces. Utilizing the actor network theory to draw connections between the evidence presented and the co-production theory, there are several actors within this technological "network." Space industries can be grouped into a single actor entity with the objective of advancing self-benefiting commercial interests while contributing to social advancements in technology. The satellite mega constellations are another actor with objectives of occupying space domain. Lastly, astronomers raising concerns over mega constellations are the third major actor in this network with the objective of mitigating interference of space debris on other fields of scientific research, such as astronomy.

Together, this complex network serves as one example of co-production. The connotations stemming from space debris in the form of satellite networks is continuously evolving depending on the degree of interference impacting scientific fields of research. As the discourses surrounding commercialization of space continue to evolve, so do the views on space debris. Space debris is not necessarily a negative entity, it just depends on the societal circumstances in which this entity exists. In a society where outward expansion into space was prioritized over all other fields of science, there would likely be little change in the discourse of what space debris is categorized as and thus the practical effect and meaning assigned to the debris would hold steady over the course of its existence. Analysis of the two aforementioned sources of evidence provided insight into the how society defines and views space debris. The scientific ideas and beliefs are dynamic and are set to change as more major actors take on roles

within the network previously outlined. In the following research discussion, evidence will be presented which supports the STS framework of technological momentum.

Technological Momentum

In his 1984 essay titled *Technological Momentum,* Hughes argues that newer forms of technology are more susceptible to sociocultural influences while older, more established, forms of technology are more deterministic in nature. Space technology is constantly evolving to fit the demands of society and with these evolutions, social and technical forces must be equally weighted in determining the effects of space debris on society and developing technologies. A point that Hughes makes in his essay which fits the narrative of space debris being a self-determining entity is that once sociotechnical systems gain momentum, they appear to have a mind of their own. Hughes' reasoning for this is that social structures such as government, corporations, and industries incentivize minimal changes to existing systems in an effort to streamline sociotechnical innovation. In this sense, more established forms of technology have more pull in influencing society as existing social structures have to work "around the edges" to accommodate newer forms of technology. In the evidence that follows, space debris will be categorized as a well-established form of technology that social systems have to work around. The effects of space debris will then be related back to technological momentum with the goal of answering the research question.

The possibility of space debris becoming a threat outside of society's control has been considered since the late 1970's. This scenario has been dubbed as the Kessler syndrome; it states that "as the density of space rubbish increases, a cascading, self-sustaining runaway cycle of debris-generating collisions can arise that ultimately make low-Earth orbit too hazardous to

support most space activities" (David, 2021). Donald Kessler, a retired NASA researcher stated that "there is now an agreement within the community that the debris environment has reached a 'tipping point' where debris would continue to increase if all launches were stopped." A new form of technology seeking to "work around" space debris is the End-of-life Services (ELSA-d) which consists of a satellite designed to safely remove debris from orbit (David, 2021). Utilizing magnetic technology, the team of scientists behind the project hope to inspire other teams of scientists to adopt similar technologies to remove space debris. Such a form of technology is an example of how older forms of technology inspire changes in social evolution—in this case technological innovation. The momentum behind the current project serves as an example of a cascade effect. Once space debris removal technology establishes a solid foundation in society (its purpose is well documented and addresses ongoing issues in space environmentalism) then branches of similar technologies will see a rapid growth in presence. In this sense, space debris as an entity and form of technology drives sociotechnical change and vice versa.

Study Limitations and Future Review

The scope of the research was limited to resources readily available for access. This potential flaw in the research might have limited the breadth of evidence available to support the STS frameworks initially chosen. Additional resources from interviews and survey data may have added additional certainty into the degree to which space debris impacts emerging fields of science as well as the general population. Opinions such as "perceived threat level" and "personal significance attached to satellite dependent devices" could have changed the direction and outcomes of the research. Additionally, there may be underlying biases in the research articles chosen which exaggerate the threat of space debris and its impact on society. Areas of

concern within the scientific community tend to snowball in severity especially when the focus subject is a topic of interest outside of the scientific community. Commercial ventures such as SpaceX have sparked new interest in space capitalization and thus the scientific community may have sought an opportunity to take advantage of space debris' relevance.

If this study were to be continued or utilized in future studies, there are several changes that would be worth investigating. For one, more sources featuring quantitative data should be utilized. Quantitative data would add value and credibility to the degree of influence space debris has. This study does feature some quantitative data such as the number of existing space debris on record, but quantitative sociotechnical data would prove to be useful. Examples of data include "how many devices are reliant on satellite networks," "the impact of one satellite outage," and "revenue generated from space commercialization." An additional recommendation for future research involving space debris is the forecast of the threat with considerations of military and commercial involvement. Lastly, this field of discussion is dynamic in that space debris is entering Earth's orbit faster than what society can currently remove. Researchers should investigate emerging and existing policies as well as economic interests in minimizing space debris.

In summary, this paper served to answer the question of how technology, in the form of space debris, as a self-determining entity in space impacts social, economic, political and other forms of developing technology. With research and discussion surrounding several STS frameworks, it was determined that space debris and society impact each other and evolve alongside one another. The research question proposed framed space debris as a potential influence for sociotechnical change. With the research presented, and the compelling argument made using the co-existence framework, it was also determined that space debris should not be

analyzed as a stand-alone form of technology. The significance of its impact on social, economic, political, and other forms of technology varies depending on the context of and scale of its relationship to potential areas of influence. For smaller areas of influence such as everyday technology including smartphones and computers, etc., the scope of its impact is far-reaching and significant. For larger areas of influence such as science, its impact is far more limited due to the resources presently available. Until the issue of space debris garners a larger following and base of interest, it is unlikely that its impact can be thoroughly investigated.

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