An Investigation of the Societal Benefits of Space Exploration

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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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Abstract

The advancement of space exploration initiatives has introduced a new era of science, technology, engineering, and mathematics (STEM). The primary focus of this research is to identify the relevant stakeholders involved in the exploration of space, and to analyze the unintended consequences that occur, or may occur, as a result of such developments. The consequences under consideration will include, but not be limited to, tangible outcomes such as the development of a new technology, and intangible outcomes such as resulting societal trends. Actor network theory (ANT) will be employed in order to identify the relevant actors and delineate the respective relationships between each of the actors. The explicit end goal of this research is to substantiate how space exploration has served to benefit society, and how it may continue to benefit society in years to come.

An Investigation of the Societal Benefits of Space Exploration

Foreword: I have greatly deviated from the work outlined in my prospectus. The title of my STS research paper has changed, and my technical project has also changed. Instead of utilizing satellite technology to solve the issue of truck parking, my technical project is now concerned with utilizing satellite technology to measure adverse weather conditions on roadways in Virginia. I have also decided to strictly focus on space exploration's effects on the US educational infrastructure.

Introduction

As the exploration and commercialization of space has become more commonplace over the past few decades, and will continue to for the next several decades, it is important to consider why it is worthwhile despite the existence of a multitude of problems on Earth. The ultimate goal of this work is to answer the question: "how can space exploration be leveraged to solve sociotechnical problems on Earth?" The answer to this question has the potential to reveal entirely new avenues through which Earth-based problems can be solved more effectively from outside Earth's atmosphere than within it. Steve Dick, one of NASA's previous chief historians, illustrates the importance of this study by stating that the "societal impact of spaceflight is in need of systematic scholarly examination" (Dick, 2007). In the context of this research, "space exploration" refers to any human or technological excursion or voyage in space beyond the boundaries of Earth's atmosphere. For the purposes of conciseness, this research will only focus on space exploration conducted by organizations and entities based in the United States (US), with much attention devoted to the Apollo program.

Historical Context – The Space Race

The Apollo program is representative of the traditional view of space exploration – the demonstration of engineering prowess to achieve the unprecedented goal set forth by the federal government of placing a man on the Moon (Grossman, 2009). At surface level, the Apollo program was a pivotal US initiative in the Space Race characterized by ambition and ingenuity. However, the Apollo program represented far more than a collection of brilliant astronauts, engineers, and NASA officials – it represented democracy in stark contrast to communism. The Space Race was simply a microcosm of a much larger conflict between the US and the Soviet Union. This conflict is notoriously known as the Cold War. Tensions were high between the two nations, and were further exacerbated by the threat of nuclear warfare. The inevitability of mutually assured destruction led the US and the Soviet Union to pursue other avenues in order to gain an upper hand, and both nations ultimately turned to space.

The first major victory in the Space Race was claimed by the Soviet Union in 1957 when they were the first to place a satellite, Sputnik I, into orbit. After both the US and the Soviet Union claimed other minor victories in the Space Race, it became very clear that the true champion would be the first nation to land a man on the moon. Landing a man on the Moon was viewed as a national victory on a monumental scale, and it would highlight the victor as the most technologically advanced nation in the world. The motivation behind John F. Kennedy's message in his famous "man on the Moon" speech was truly to "best the Soviet Union and show the world the strength of a free society" (Chaikin, 2007). The issue for both the US and the Soviets was that the technology necessary to propel people to the Moon did not yet exist. Therefore, the accelerated development of space technology in the Space Race was warranted by government action and nationalism in the context of a war between political ideologies. Aside from bolstering nationalism and demonstrating global superiority, there are several other consequences of the Space Race. The improvements in STEM education in the US that resulted from the Space Race, and more specifically the Apollo program, will be further analyzed in this work. This analysis will indicate the manner in which the political rhetoric and public sentiment of the Apollo era engendered technological advancement, which set in motion a perpetual interplay between societal influences and technology.

Foundations of Actor Network Theory

Space exploration offers a unique perspective regarding who and what the relevant sociotechnical forces and outcomes are through the lens of Bruno Latour's actor network theory. In the framework of ANT, social determinism and technological determinism are allowed to coexist in a vast network of heterogeneous social and technological actors (Latour, 1992). ANT allows nonhuman actors to assume the role of human actors, and vice versa, which in effect levels the playing field and is conducive to a more holistic and unbiased analysis. The three core principles of ANT are agnosticism, generalized symmetry, and free association (Tabak, 2015). The principle of agnosticism prompts the researcher to abandon any pre-existing, popular assumptions of the network, and to perceive the entire system with arbitrary interpretation. Doing so invites the possibility of producing novel ideas rather than expounding upon old beliefs. Generalized symmetry supports the idea that all actors are to be treated equally, and their analyses should thus be conducted in an identical manner. The principle of free association serves to eliminate distinction between material and social forces, and to perceive them both as results of the behavior of the network as a whole. The aim of this work is to analyze various space exploration initiatives by breaking down each comprehensive network to identify the relevant actors, how they interacted, and what outcomes they produced.

The Space Race's Role in Education Reform

In many ways, the launch of Sputnik I can viewed as an analog to the American Revolution's "shot heard around the world" in the context of the Space Race. Thomas Kessinger notes that the successful launch of Sputnik I "presaged and advanced a great concern in the United States that out school systems were inadequate" (Kessinger, 2011). At a time when the general public sentiment in the US was that the Soviet Union had a superior education system, Sputnik I provided the impetus needed to funnel funding into STEM education programs under the guise of national defense. In reality, the purpose of this directed funding was twofold: to appease those who felt that American education was slacking, and to bolster US ability to best the Soviet Union in the Space Race and ultimately the Cold War. Records from the National Science Foundation (NSF) show that on October 4, 1957, Congress responded to the successful launch of Sputnik I by "more than doubling the NSF appropriation" in their budget, while more than tripling education funding (A Timeline of NSF History, n.d.). These appropriations were allocated to federally funded STEM research projects across the US. In October 1958, Congress invoked the National Defense Education Act (NDEA), which was intended to bolster American STEM education by providing a substantial amount of student loans, improving professional development of educators, developing programs to identify and empower academically gifted students, and generating standardized testing as a measure of effectiveness (Jolly, 2009).

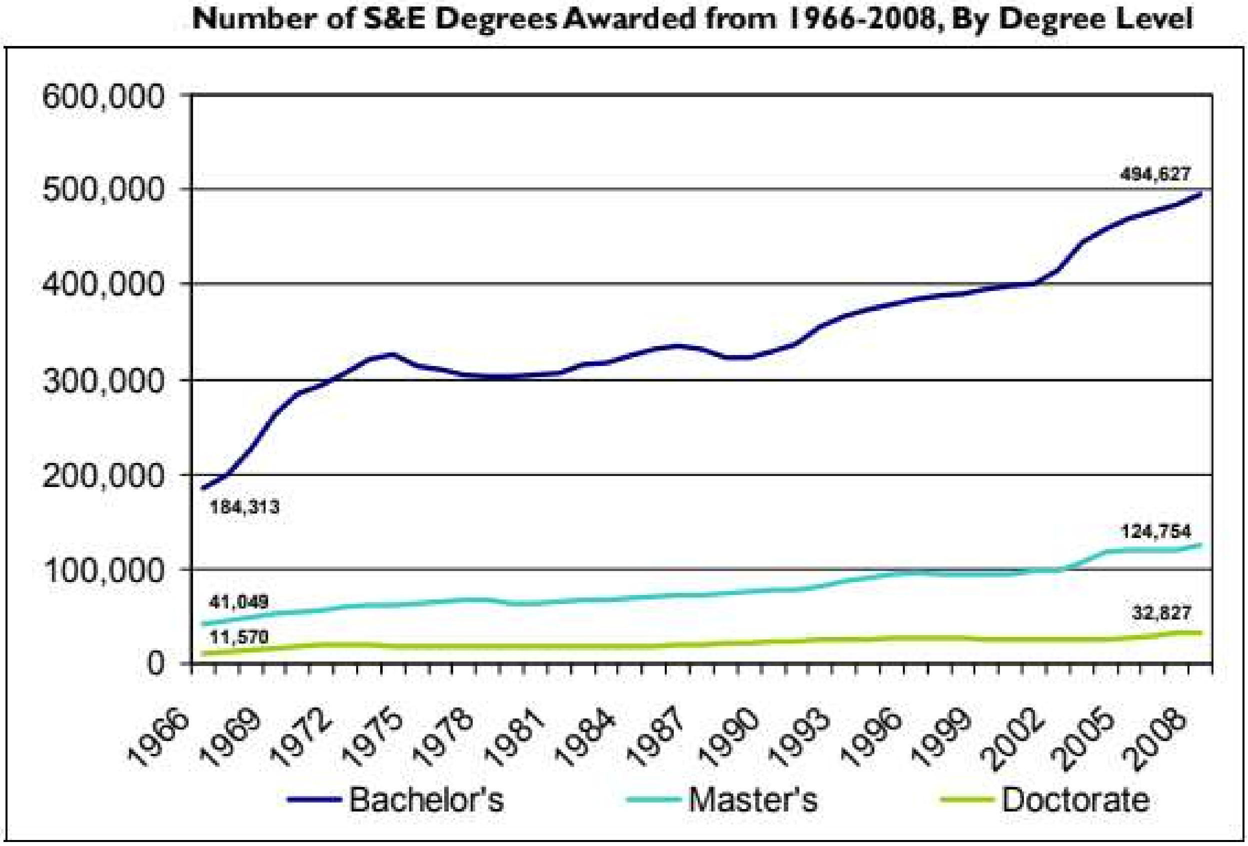

Figure 1. Plot of bachelor's, master's, and doctorate degrees in science and engineering awarded from 1966-2008. From: Gonzalez, Kuenzi, 2012

Figure 1 shows that there is a greater than 50% increase in bachelor's degrees awarded between the years of 1966 and 1975. Generally speaking, the students earning these degrees would have completed grade school over the course of the Apollo missions, and would certainly have been exposed to the increased financial and educational efforts to improve STEM education through the NSF and NDEA. Therefore, the data suggests that a primary, unintended consequence of the Space Race was the rapid emergence of an entirely new and inspired generation of scientists, technologists, engineers, and mathematicians. While the data in Figure 1 appears to show little to no variation in the trends for doctorate degrees, the reality is quite the opposite.

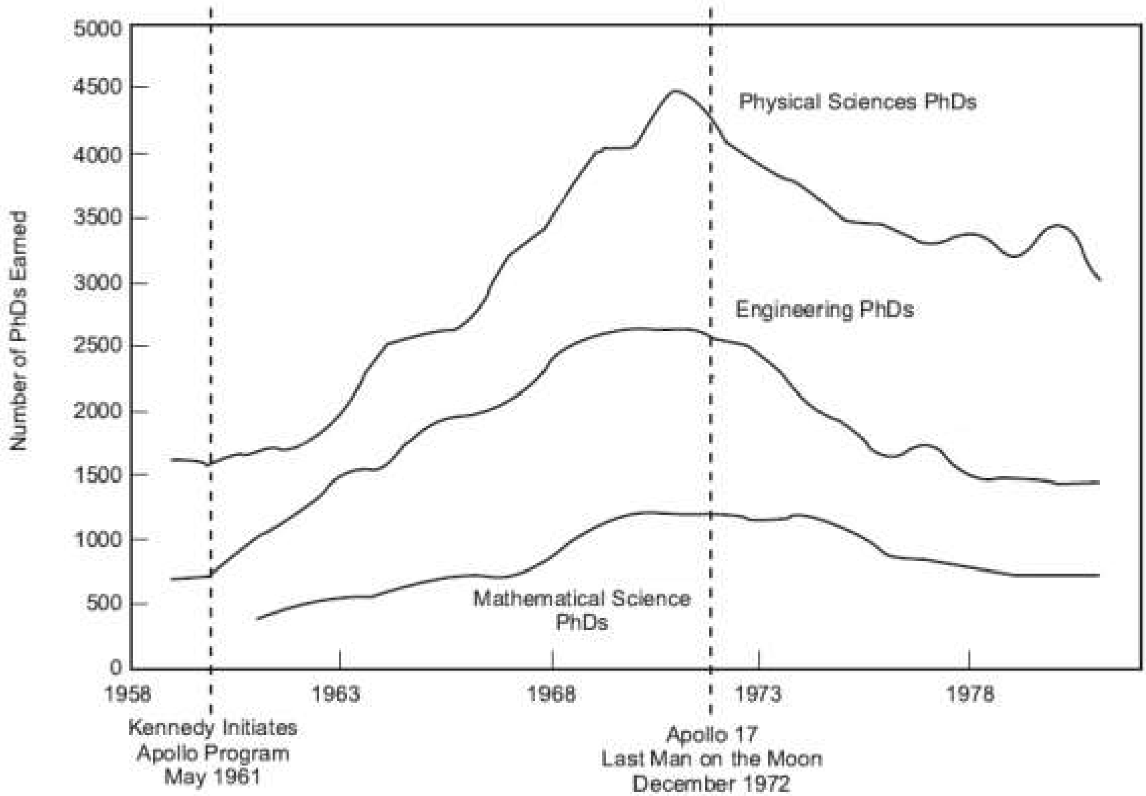

Figure 2. Plot of doctorate degrees awarded in the physical sciences, the mathematical sciences, and engineering. From: ("Benefits Stemming from Space Exploration", 2013)

The data in Figure 2 shows that there was in fact a dramatic increase in doctoral degrees awarded during the era of the Space Race. Mathematical science PhDs increased by more than 100%, Engineering PhDs increased by more than 300%, and physical sciences PhDs increased by roughly 180%. While correlation does not necessarily indicate causation, it is equally plausible to attribute these trends to the aforementioned financial initiatives in STEM education and that the peak in each trendline occurs roughly around the end of Apollo. To further substantiate this claim, data from a survey conducted by the journal *Nature* indicates that roughly 50% out of 800 previously published researchers in the journal were inspired by the lunar landings of Apollo 11 to pursue a career in scientific research (Monastersky, R.). It is also interesting to note that the number of STEM doctorate degrees awarded happened to drop drastically after the Apollo era.

Another aspect of educational reform that was engendered during the Space Race was improvements to the theory of education itself. As previously mentioned, one of the aims of the NDEA was to improve educators' ability to teach. These efforts are clearly demonstrated by a large increase in education research, as shown in the table below.

Table I. Education research dissertations, total and biology-related (1930-1989)

Decade	Total	Biology	% Biology
1930-1939	435	2	0.46
1940-1949	581	4	0.69
1950-1959	2212	21	0.95
1960-1969	2780	27	0.97
1970-1979	7396	97	1.31
1980-1989	*17992*	250	1.39
Total (1930-1989)	**31396**	**401**	**1.27**

Source: DeHaan, 2007

Table I reveals the post-World War II sentiment of educational improvement, with education research dissertations jumping from 581 to 2212 between the 1940s and 1950s. More importantly, the data in Table I indicates that there was another sharp increase in education research dissertations during the intra-Apollo and post-Apollo eras.

Discussion

Relevant Actors and Their Relationships

The ostensible victory of the Apollo program is that the US solidified its stance as a global superpower and demonstrated that democracy bests communism. However, when analyzing the Space Race in the framework of ANT, the assumption that the Apollo program and its efforts were strictly political must be abandoned in accordance with ANT's principle of agnosticism. Accordingly, it is fruitful to consider how the technology and the relevant social forces collaborated in a cohesive manner to facilitate a positive outcome in the form of improvements to the US educational infrastructure. To begin with, there was already a sentiment that American education was inferior in the aftermath of World War II as reflected in Table I. In Vannevar Bush's report to the President in 1945, he asserted the importance of the formation of an organization to be tasked with providing financial support and incentives to undergraduate and graduate students pursuing scientific inquiry. This proposal ultimately led to the formation of the NSF in 1950, which laid the groundwork for federally funded research projects to be undertaken in academia (Bush, 1945). Shortly following the inception of the NSF, NASA was founded just days before the NDEA was enacted with the explicit purpose of advancing US interests in space. The trends in science and engineering degrees awarded following these developments are displayed in Figures 2 and 3. It can therefore be argued that the Soviet Union and Sputnik I were equally as important to the improvement of American education in the 1950s and 1960s as American entities and initiatives were.

In addition to the aforementioned political landscape, the television was just becoming commonplace in the average American's household, providing a perfect opportunity to broadcast live audio and video of American astronauts in space. The livestreaming of the Apollo missions naturally attracted the attention of the media, further exposing the public, and more importantly grade-school-aged youth, to the incredible accomplishments that mankind was making in space. The technology that was developed and implemented to accomplish each mission played an equally important role in US education reform. Mission requirements necessitated more advanced technology, and the technology being developed served to solidify and open the door to more advanced and specialized fields of study within STEM. The comprehensive network under consideration that led to educational improvement in the US is therefore comprised of media – television and live streamed space missions, political forces - US and Soviet governments, social forces – sentiment to improve American education after World War II, and the technology that supported the Apollo missions.

In effect, each of these actors have assumed both human and nonhuman roles in the advancement of US education. The media, a materially nonhuman actor, served as an apparatus to display human excellence and ultimately to evoked emotional response from viewers, which is inherently an act carried out by humans. Space technology, also a materially nonhuman actor, paved the way for more advanced curriculum and fields of scientific inquiry, which is typically the directive of an educational organization. Similar descriptions can be attributed to each actor, highlighting the utility of incorporating arbitrary materiality in the framework of ANT, where actors have different material interpretations depending on their function and purpose, but ultimately contribute equally to the overall behavior and intention of the network which is to advance STEM education in the US in the explorational pursuit of a new frontier. The actors and their aforementioned relationships as described above are depicted in Appendix A.

Arguments Against ANT

One of the difficulties, and arguably one of the limitations, of applying ANT to analyze sociotechnical phenomena is the assumption that the network under consideration is completely isolated and all external forces are negligible. The actors and relationships described in this study are in no way exhaustive. In actuality the actors and relationships are infinite in quantity and extent. For example, a worker at a steel mill that forges the steel that is to be incorporated into each spacecraft is considered just as essential as those who designed and physically built the spacecraft. It is therefore necessary to draw a line that separates those actors which should be taken into consideration, and those which should be neglected. Pertaining to the analysis conducted in this study, the actors that were identified as relevant are those which comprise a larger entity that extends beyond individuality. Although this distinction may sound arbitrary, it is intended to narrow the focus of the study and neglect the individual actors such as the steel mill worker.

Conclusion

This research was intended to highlight the complex sociotechnical interactions that engendered an entirely new generation of scientists, engineers, and mathematicians. These interactions were demonstrated through analysis of data showing STEM degree awards over time, policy documents that directly addressed the shortcomings of the US educational infrastructure with funding, and appeals to the US government for a progressive improvement in STEM education through programs like the NSF. The analysis in this work revealed that the Space Race and educational improvements in the US are simultaneously results of social and technological determinism. Further extensions of this work might be interested in studying space exploration’s effect on improvements to healthcare technology and medical science, as suggested by Simon Evetts in his proposal to leverage space exploration to improve healthcare practices (Evetts, 2014). Additionally, it may be fruitful to focus future efforts towards how these sociotechnical interactions would fit into the contemporary trend of the commercialization of space. It has been proven that in the year 2000, the number of foreign students pursuing graduate degrees in US schools surpassed the number of American students (Augustine, 2007). This invites the opportunity to consider how space exploration might yet again provide the impetus needed to bolster American education.

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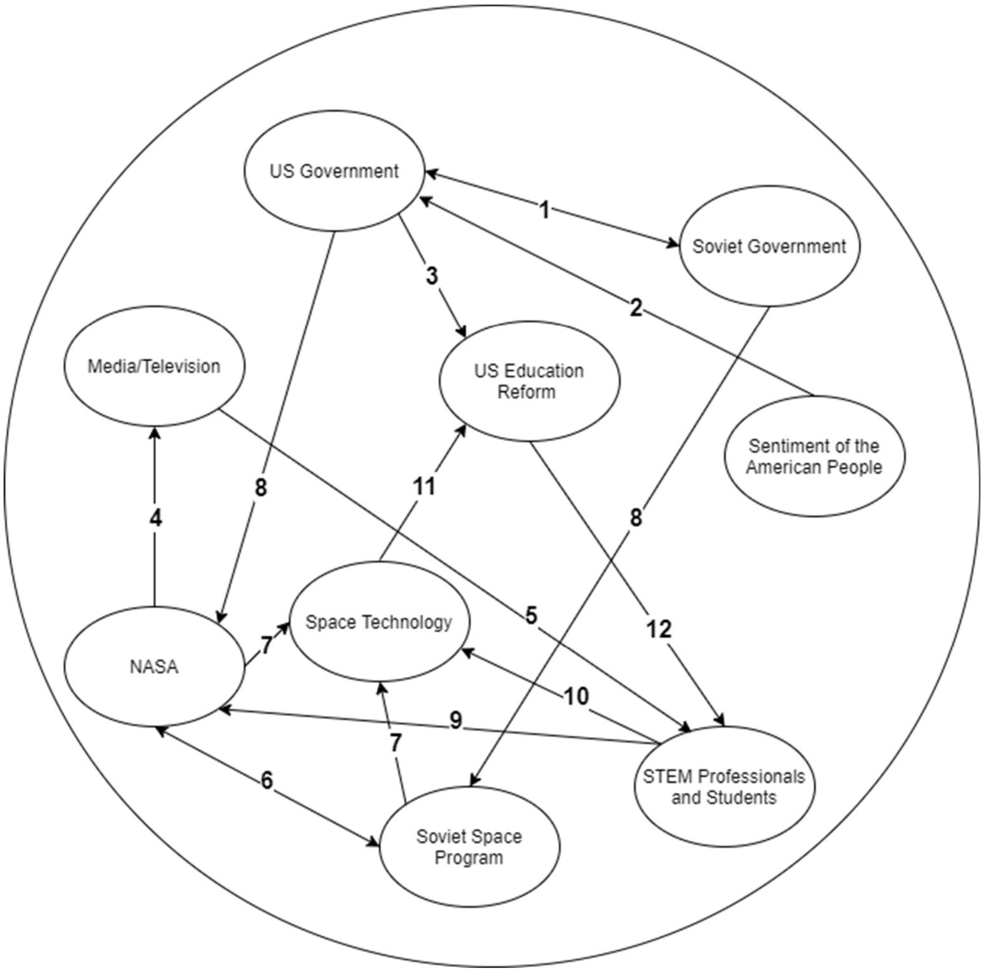
Appendix A



1. Political tension
2. Lobbying efforts, reports to President
3. Funding via NSF and NDEA
4. NASA livestreams audio and video of Apollo programs via television/radio
5. Media inspires a new generation of STEM students
6. Competition between space agencies
7. Technology is produced via innovation
8. Governments playing a direct role in managing their respective space agencies
9. NASA receives influx of new, talented engineers and scientists over time
10. STEM professionals and students work towards scientific innovation to support space technology
11. Space technology outlines the potential for more specialized fields of study in STEM
12. Education reform generates more talented and educated STEM professionals and students