The Impact of Society on Satellite Technology and Interpretive Flexibility

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Graham Fitzgerald

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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

Advisor

S. Travis Elliot, Department of Engineering and Society

Introduction

Satellites have quickly become an indispensable tool for today's society and the individuals and organizations that command its direction. With 3372 operational satellites currently in Earth's orbit or slated to be launched to Earth's orbit by December 31, 2021, there is no shortage of planetary satellite coverage. However, of the 3372 operational and planned satellites in orbit around Earth, 1897 belong to the United States, 412 belong to China, 176 belong to Russia, and the other 887 are split among over 100 other nations worldwide (Union, 2021). While there are a select few satellites and probes currently exploring the other planets and astral bodies in the solar system the majority remain in Earth's orbit consisting of 54% commercial satellites, 16% government satellites, 13% military satellites, 5% civil satellites, and 12% of satellites used for a combination of purposes (Wood, 2020). With a wide distribution of country of origin and purpose across all orbiting satellites, there is history and a relationship between the technology and the society that created it behind each satellite.

The technical portion of this thesis attempts to design, create, and launch a small satellite (called a CubeSat) into space to determine if it can be used to track weather conditions on roadways. The satellite will be outfitted with a multi- or hyper-spectral imager with the capability of covering a 32 square km area at a 9.6 m resolution from a 500 km altitude. This means that a relatively small area can be accurately analyzed for ice, snow, or other hazards from a low earth orbit (LOE) by measuring for certain wavelengths of light (CubeSatShop, 2019). The results for this project will be based purely on research and information derived from textbook knowledge, subject matter experts, and in the context of the technical project, loosely tying it to the STS topic, this shows flexibility in the usage for such technology. Satellite imagers, and to a greater extent satellites, have a variety of uses, and the ability to detect certain

wavelengths of light from LOE resulted from many problems solved in the past. In turn, a network of satellites could someday be placed into orbit with the capability to scan all roadways in whatever area required, providing frequent images and information to a centralized dispatch or directly to drivers via car applications.

This paper seeks to explore the impact that satellites have had on society through the lens of the STS framework Social Construction of Technology (SCOT). From the beginning of its history of usage, during the Cold War period of the 1950s through 1980s, the satellite has provided nations and organizations with the capability to monitor and communicate with distant areas of the world. Through the lens of the SCOT framework, the influences that satellites have had on commercial, governmental, military, and exploratory efforts, as well as their effect on the progress of today's society, will be explored. Additionally, the paper will describe how satellites have advanced based on the ever-changing needs of interest groups and how these interest groups have found new uses for existing satellite technology.

Background and History

While fictional descriptions of satellites date back to the mid-19th century, the first satellite to be launched into space was Sputnik 1 in 1957, a small research satellite sent by the USSR to provide information concerning Earth's atmosphere. In turn, the United States launched their own satellite, the Explorer 1, in 1958 to study the Van Allen radiation belt surrounding Earth. While these singular launches may have been innocuous enough, they occurred during the Cold War between the United States and the USSR, thus spurring on a decades-long space race (NASA Jet Propulsion Laboratory, 2014). In this period, lasting from the launch of Sputnik 1 to the dissolution of the USSR in 1991, there may have been competitive intentions behind such ingenuity, but by pushing space exploration to the forefront of

government and public efforts, men were able to walk on the moon and new planets are being observed for future human travel.

Many of the other satellites launched during this time period were also used for research and science, such as the continuations of the Sputnik and Explorer programs. Other countries, such as England and Canada, launched their own satellite programs, but the majority of satellites made were used for other purposes. The main goals for each involved nation at the time were to gather intelligence on Cold War opponents and to create better systems for communication between people across the nation or across an entire ocean. Some of the best documented (and recently declassified) examples of intelligence satellites are the GAMBIT and HEXAGON programs, developed by the United States and kept in operation for the duration of the Cold War. These rudimentary devices consisted only of a small housing, a high-definition camera, and the rocket used to propel it to space. Over the course of its 6-day mission, they would take images of military instillations in the USSR and China, returning the camera afterwards to Earth in a special capsule so the film could be developed (NMUSAF, 2015). As camera quality developed simultaneously, such missions became more advanced. Today the same concept is used for a variety of civil projects like monitoring road conditions, but the concept was only explored due to necessity created by the space race. As well, communication satellites were a large priority to ensure that troops in conflicts like the Vietnam War could communicate using satellite phones. The first communication satellite, Telestar-1, was launched in 1962 by the United States and allowed communication of TV and radio signals from across the Atlantic Ocean, paving the way for satellite television that is still widely used today (NASA Jet Propulsion Laboratory, 2014). In fact, companies like AT&T took immediate advantage of the capabilities of communication satellites, allowing them to grow into the commercial conglomerates they are known as today.

Probably the most enduring legacy of satellites, however, is the scientific exploration of the solar system and beyond. As early as 1959, scientists have also sought to explore past Earth's atmosphere to Earth's moon and beyond. This was accomplished through programs like the USSR-made Luna satellites, consisting initially of rudimentary atmospheric instruments and, later, durable satellites with landing capabilities (Pallardy, 2009). While initially these satellites were used to further the goals of nations in the space race, with research on the moon's atmosphere and surface used to eventually land men on the moon in 1969, missions since then have sought to explore further planets like Venus and Mars, and even other astral bodies like Halley's comet and the sun. Though still seen as points of national pride for their respective nations, these satellite missions, especially since the fall of the Soviet Union, have been mostly scientific and exploratory in nature, seeking only to test the limits of human ingenuity. The modern purpose of satellite exploration is a far-cry from its original purpose, but without a decades-long Cold War and space race, spurring a wave of interest, research into this field may have been significantly delayed.

STS Framework: Social Construction of Technology

Before delving into the long-term benefits and detriments of satellite technology, it is important to first understand the social science that governed its popularity and continued interest from not only science groups, but also the world at large. Scientists were pushed to create better and more technologically advanced satellites by the social factors of the time (i.e. the space race). When this situation is viewed through Social Construction of Technology (SCOT), a technological theory which states that certain inventions and innovations were brought about due to external demand and interest, separate from academic influence, the causations behind unmanned satellite research is clear. The three main components of SCOT:

interpretive flexibility, technological frame, and relevant social groups, as seen in Figure 1, work together to define the development of an artifact (Yousefikhah, 2016).

Interpretive flexibility is the glue that binds this theory together; simply stating that there is more than one use and one interpretation of any artifact in history. This means that, regardless of the initial reason for the development of a technological advancement or invention, third-party interest may seek to advance the scope of the artifact past its intended field. For instance, silly putty was invented during World War II by chemists at General Electric as a synthetic substitute for rubber, as demand for rubber was high in making wartime equipment. However, proving to be a poor substitute, the project was scrapped until, years later, it was made into a children's toy, as it is known today (National Toy Hall of Fame, 2001). The second tenet of SCOT is the technological frame of the time period, wherein the nature of the technology and the technology strategy for an artifact are held (Yousefikhah, 2016). Nature of technology is the idea that technology can only be intended for use within the scope of the minds of its users, regardless of any externalities that may occur, and technology strategy is described as the incentive behind the usage of said technology. In the silly putty example, the original creators of silly putty saw it only as a poor substitute for rubber, while another party was able to see silly putty as a safe, marketable toy for children, thus increasing the scope of its usefulness. The last section of SCOT is the collection of social Groups involved, including producers of the technology, advocates and financiers, the users of the technology, and bystanders that, while not directly involved, may be affected by the societal change that the artifact brings about.

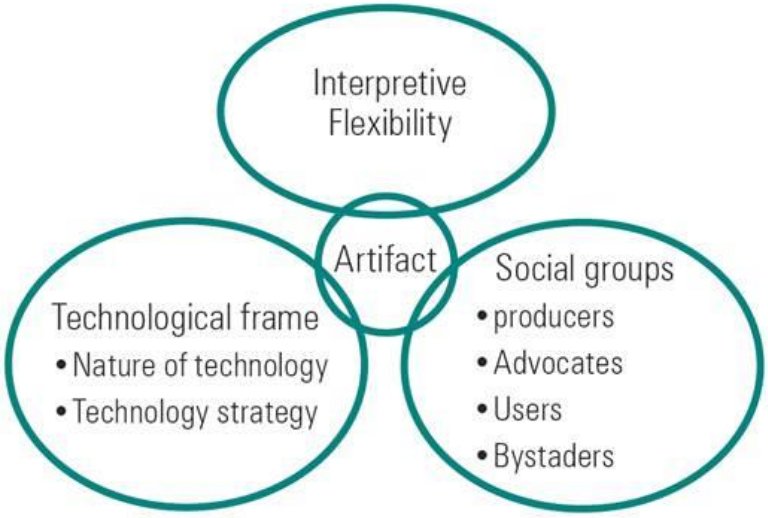

Figure 1: Diagram highlighting the three important, interconnected pieces of SCOT (Yousefikhah, 2016)

Just like silly putty, satellite technology was heavily influenced by forces outside the realm of academia and research, and, while the original purpose did not fail, other uses were found to be more beneficial for all parties involved. The two initial main players in the history of this artifact were the science groups involved (producers) and the governments and large organizations that were interested in the technology for their own purposes (advocates and users). As well, there was pressure from the general public of nations involved in the Cold War (bystanders) to launch the next satellite and to prove the superiority of the nation. The interpretive flexibility for satellites was present in the different goals of governments and research groups, allowing for the eventual diversification of satellites, but the Technological frame of the time, including the undeveloped technology, and pressures from all social groups limited the use possibilities until a less-tumultuous time.

Reciprocal Impact of Satellite Technology on the Course of Society

Just as research by scientists and influence by prominent figures pushed the development of satellites further, the capabilities and possibilities of satellite technology, intended and unintended, also pushed society forward. The original uses for satellites were exploration and research, and while those are still a few of the technology's main purposes, other actors and bystanders sought to use it in other ways. As mentioned previously, companies like AT&T almost immediately took advantage of the structure and transmission capabilities previously designed for planetary and space research to transmit commercial radio and television signals (NASA Jet Propulsion Laboratory, 2014). This, in turn, greatly expanded the commercial communications field and paved the way for satellite television and cell phone coverage. However, without the initial creation of satellite technology for political reasons, this would not have been possible. Therefore, in this case and many others, there is a link between society's effect on the construction of a certain technology and the technology's effect on the path and technological timeline of society.

Societal Impacts of Satellite Technology and Subsequent Advancements

Economic Impacts

The historical and potential future economic impacts of satellite technology are constantly evolving and multi-faceted. Large sections of the economy, from the still-emerging space manufacturing and investing industry sectors to telecommunications and consumer services, benefit from this technology every year. As seen in Figure 2, significant portions of the global space economy are attributed to satellite manufacturing and launches, consumer services

like TV and radio, navigation services like GPS, and other services required to bolster today's economy (World Economic Forum, 2020).

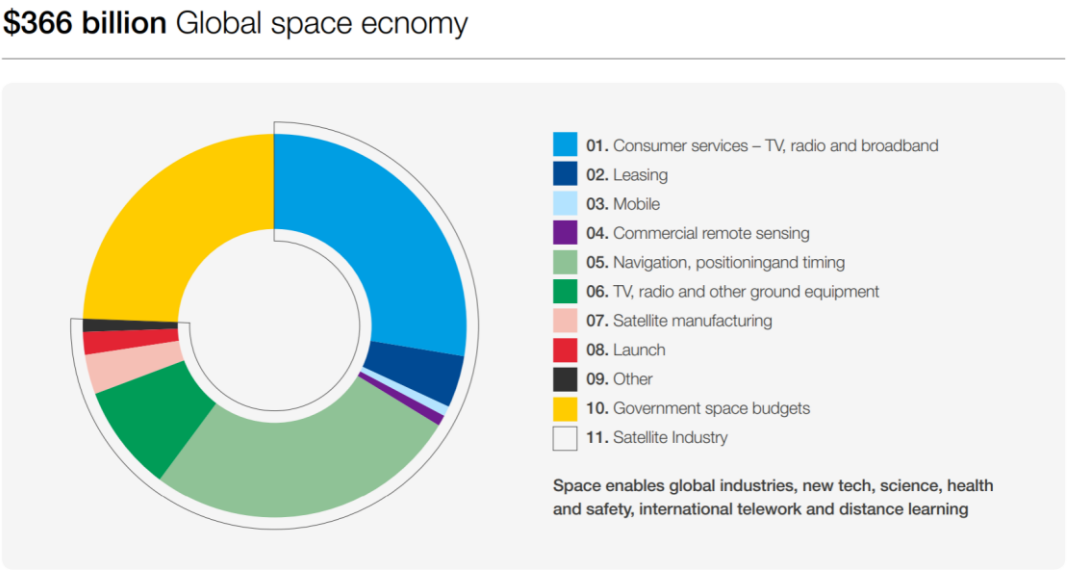

Figure 2: Divided economical gains dependent on space technology, with the bordered area representing gains attributed to satellites (World Economic Forum, 2020)

The most prevalent economic sectors concerned with the satellite economy is consumer services and commercial enterprises. In 2019, commercial satellite services grew to be a $271 billion industry, with markets like broadband internet growing 18% between 2018 and 2019 as technology has gotten better (Satellite Industry Association, 2020). The commercial sector affects anyone that uses a smart phone, satellite television, broadband internet connection, or a myriad of other related systems, accounting for such a steep increase in commerce. In addition, the market for ground equipment intended for these satellite services grew by 4% between 2018 and 2019, resulting in a $130 billion industry. This sudden increase is most likely attributed to the continued rise of smart phones, tablets and other global navigation satellite system (GNSS) terminals (Satellite Industry Association, 2020). One subdued element of commercial satellite

enterprise, however, is the navigation industry. While the United States government, and other governments in more recent years, control most of the Global Positioning System (GPS) satellites in orbit, much of the data provided by GPS is used in commercial products sold to consumers. A small yet important section of the global satellite economy is additive manufacturing and launch capabilities. Mostly comprised of work from aerospace firms like Lockheed Martin or Northrup Grumman, specialized satellite manufacturing takes skilled labor and a close relationship with scientists behind the project. An appropriate launch area is also required to launch satellites into space, sometimes requiring a rocket already slated for launch to be available for satellite attachment. Satellites are a very large portion of the current global space economy and great collaborative advancements can be made in the future.

Through the lens of SCOT, the key stakeholders for the economic side of satellite technology include firms like Northrup Grumman, the individual workers and scientists behind new innovations, and organizations with launch capabilities for satellites. From launching organizations (users) to manufacturing firms (producers) and down to individuals, each one of these actors are interconnected through the transfer of money. This cash flow is vital to the success of all actors, and the needs of consumers and businesses alike have driven satellites to be used for more than their original purpose thus demonstrating interpretive flexibility. There must always be a new mission purpose to warrant the manufacture and launch of new satellites, forcing stakeholders to devise new missions for existing technology and to constantly advance technology. In this way, stakeholders are very positive in their outlook of satellites, if only as a way to make money, but do not actively try to influence others' interpretations outside of this cash flow. Therefore, closure on the economic side of satellite technology has been achieved.

Social and Military Impacts

As mentioned previously, satellite technology affects any average person with a GNSS system such as a tablet or smart phone. Satellites allow people with this technology to reliably teleconference with other people across the world. Most people simply video chat with friends and family, but doctors, caregivers, and teachers have also been able to teleconference with patients and students. This not only allows for medical diagnoses and specialist opinions without the need for travel, but it also allows for knowledge to be shared with a larger audience (Gottschalk, 2017). While this may be important to advance the well-being of developing nations, it has also been crucial during the COVID-19 pandemic, allowing for continued operations in many social and economic sectors while social distancing. Another common use for GNSS systems is GPS navigation. Before its inception, maps were the best way to figure out how to get from location A to location B. GPS has allowed people to navigate more easily and, combined with other communication services, has made the world feel more connected.

In the same manner that satellites have improved the efficiency of civilian programs and services, they have also improved the effectiveness military operations and the present and future of warfare. As one of the original uses for satellites, the military has benefitted greatly from advances in technology, like imaging and other intelligence gathering, and their incorporation into satellites. Whether routed through ground stations or fed directly into satellite phones, commanding officers can direct troops in even the direst situations with the current satellite infrastructure. An example of such satellites is called the Military Strategic and Tactical Relay (MILSTAR), a constellation of five jam-proof and reliable communication satellites providing for the U.S military worldwide (Lee, 76, 2014).

Both social and military uses for satellites influence public interpretation in vastly different ways. The key stakeholders in this case are civilian services with teleconference capability and military complexes with satellite surveillance and communication, both as users of the technology. Unlike the key stakeholders of the economic side of this technology, these stakeholders have a public image that sways public perception concerned with tools that these groups use, including satellites.

In the case of teleconferencing doctors, teachers, and other civilian services (users), the positive impact that making such services accessible worldwide causes bystanders and most users to have a positive perspective on the advancement of this technology. An exception to this sentiment may be some essential workers, like doctors, who must work longer hours and see more patients due to the capabilities of teleconferencing, and even then, they may still feel as though what they are doing is worth the extra time and effort. These interpretations, however, do not lead to any major problems or general dissent, allowing there to be closure between satellite technology, teleconferencing workers, and bystanders with a focus on continuing innovation.

Alternatively, in the case of military complexes using satellites for surveillance and communication, there are greater issues to consider for the users and bystanders related to such applications. In many cases, satellite technology is used in the completion of military operations that involve the elimination of targets or capturing of locations from opposing forces. Such missions can be seen in a good light, considering the lives potentially saved by eliminating someone like the leader of a terrorist cell, but an argument can be made by bystanders that any violence is condemnable. By extension, any technology used in the process, including satellite technology, is also condemnable regardless of any other known uses. Additionally, those affected by satellites in this way, even those with no impact on the construction of this

technology, may become distrustful of satellites and speak out, potentially influencing others to feel the same way. These complaints would cause no major problems in the mission operations of satellites but would prevent closure between the technology and all actors involved.

Scientific Impacts

The impact that satellite technology has had on the scientific community is enormous and has accounted for the continued interest in space exploration efforts like the exploration and potential colonization of Mars. Satellites orbiting Earth have also allowed scientists to learn more about the planet and to keep watch on problems affecting natural and man-made environments. Since television shows like Star Trek aired in the late 1960s, public opinion has followed the scientific community's efforts to learn more about the solar system and galaxy surrounding Earth. Notable missions by NASA, including VOYAGER and MESSENGER, have travelled to every major planetary body in the solar system to better understand the differences in the makeups, histories, and futures of each body. This continued interest in space and satellites, brought about so many years ago during the space race, has also kept NASA with a healthy budget to continue research and exploration into the cosmos for the foreseeable future, with NASA's budget totaling $22.6 billion in 2020 (The Planetary Society, 2021).

One other impactful, scientific use for satellites has come in the form of monitoring environments for growing problems. As the subject for the technical portion of this thesis, icing roads and treacherous road conditions caused by weather have become a large problem. If satellites with imagers can be placed into orbit to track weather systems and identify damaged or unsafe stretches of roads, then money and lives could be saved in the long run. Concerning the natural environment, a number of satellites have been used in preventing illegal deforestation, fishing, and wildlife trade. By monitoring at-risk areas, these satellites have prevented incidents

with potential costs of $73 billion per year to governments as well as possible harm to vital and endangered ecological communities that have been at the forefront of conservation efforts (World Economic Forum, 2020).

By keeping unmanned exploratory space missions, like the recent Curiosity mission to Mars, in the news and popular media, scientific organizations are ensuring that the public keeps a steady, positive interest in space and in satellites. This helps to nullify the argument that funds would be better spent elsewhere and allows for closure between the technology and stakeholders involved.

Conclusion

Taking into consideration the impacts that satellites have had on society and the innovations of society based on existing technology, it is important to reiterate the idea of interpretive flexibility. This is the idea that technology can be used in different ways based on the interpretations of society and explains how the same base satellite frame can be used to transmit television signals for private companies and crucial mission details for military personnel. As one of the main tenets of SCOT, interpretive flexibility plays a key role in continuing the construction of technology by introducing existing technology, like satellites, to new actors with different interpretations. From there, social construction of this technology can begin on a new track. Interpretive flexibility and technological innovation are intertwined and allow for continued innovation by an ever-growing number of stakeholders.

Of all the technologies researched and invented in the 20th century, there are few that have been as impactful as satellites. As a basis for many other important facets of today's society like smart phones, television, communication, and navigation, the technology has proven

indispensable. This progress will most likely continue if there is interest in or a need that can be filled by satellites, and regardless of direction, the world has been forever changed.

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