Gold and Glory: 21st-Century U.S 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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Introduction

Since 1972, human spaceflight has been confined to low earth orbit (LEO). From 2011 to 2020, United States (U.S.) astronauts reached space only in the Soyuz spacecraft launched from Russia. Human spaceflight is notoriously expensive. According to Tenner and Roland (2004), “the energy needed to lift a person out of Earth’s gravitational well would feed him for a lifetime.” To some, U.S. human space missions of the 21st century instill “not pride but embarrassment, not power but dissipation;” the U.S. has apparently been “wasting precious resources on stunts with no practical payoff” (Tenner & Roland, 2004). Louis Friedman, who cofounded The Planetary Society with Carl Sagan and Bruce Murray, has remarked that “in the 40 years since the end of the Apollo program, we have not even reached farther into space than the distance from Los Angeles to San Francisco” (Friedman 2015). Since 2011, the year of the last space shuttle mission, political support for expensive human spaceflight projects has been meagre.

John Logsdon, founder of the Space Policy Institute at George Washington University, credits human spaceflight with “delivering scientific payoffs, generating economic benefits, developing new technology, [and] motivating students to study science and engineering” (Logsdon, 2004). Friedman (2015) contends that threats “such as asteroid impact, large-scale conflict and war, pandemics, global climate change, and other types of environmental destruction” necessitate responses that may entail human spaceflight. To its advocates, human spaceflight is one of many capacities that must be developed if humanity is to manage the existential threats Friedman enumerates.

It is clear that human spaceflight has both its critics and advocates. This essay will focus on how advocates of spaceflight, human spaceflight being the telos of such endeavors, have promoted their agendas in the 21st century U.S. In doing so, critics’ opposition will also be examined. This narrowing of scope will allow us to examine the spaceflight environment and actors more closely. With some luck, this will allow us to better understand the development of the spaceflight industry and its future direction. Importantly, this essay will analyze the issue within the Social Construction of Technology (SCOT) framework, which will help us to recognize the dynamic interchange between various social groups and the spaceflight industry. A detailed discussion of the SCOT framework is first necessary to orient the reader to the analysis that follows.

Introduction of the Social Construction of Technology Framework

In their landmark work *The Social Construction of Facts and Artefacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other* Pinch and Bijker detail how the SCOT framework has its roots in the sociology of science. A subset of this sociology is the sociology of scientific knowledge. Instead of being “concerned with science as an institution and the study of scientists’ norms, career patterns, and reward structures,” the sociology of scientific knowledge analyzes the content of scientific ideas, experiments, theories (Pinch & Bijker, 1984). Crucially, this analysis does not consider the scientific falsehood or veracity of the content. The rationale for this is given: “scientific knowledge can be, and indeed, has been, shown to be thoroughly social constituted” (Pinch & Bijker, 1984). Then, both the causes, content, acceptance, and rejection of scientific claims are to be “sought in the domain of the social world rather than in the natural world” (Pinch & Bijker, 1984). This revocation of epistemological privilege from science seeks to value all types of knowledge equally. This approach has relevance for many other fields, such as science policy, the history of science, and the philosophy of science (Pinch & Bijker, 1984).

The sociology of scientific knowledge helped develop the Empirical Programme of Relativism (EPOR), an approach foundational to the SCOT framework. This approach demonstrates the "social construction of scientific knowledge in the 'hard' sciences" (Pinch & Bijker, 1984). EPOR has 3 stages: interpretative flexibility, closure mechanisms and stabilization, and relating closure mechanisms to the broader social cultural environment (Pinch & Bijker, 1984). We will examine these stages briefly.

First, interpretative flexibility describes how different interpretations of scientific observations are possible. For example, the movement of the stars in the sky led to two competing visions in the Scientific Revolution: a heliocentric solar system and a geocentric solar system. The same observation led to different conclusions in this case. The next two stages are closely related to each other. The second stage consists of closure mechanisms and stabilization. Closure mechanisms are social mechanisms that "limit interpretative flexibility and thus allow scientific controversies to be terminated" (Pinch & Bijker, 1984). From the example above, a closure mechanism would be the introduction of elliptical orbits by Kepler, or observations made using a telescope by Galilei. Overtime, the wealth of evidence in support of a given theory limits how scientific data can be interpreted and results in scientific fact.

Closure mechanisms can also take other forms. Another way of limiting interpretative flexibility is by removing the problem itself. This would be akin to saying, "What does it matter what body is at the center of the solar system?" If everyone agreed this question was valid, this would be a closure mechanism. It seems trivial in this case, but if the relevant social groups see the problem as being resolved or as a non-issue, then interpretative flexibility is eliminated. This type of closure is termed "rhetorical closure" (Pinch & Bijker, 1984). Similarly, closure can also be achieved by a redefinition of the problem. This can have the effect of presenting the problem as a solution in the new formulation of the problem. This is harder to elucidate in a scientific context but much clearer in a technological context. Lastly, the third stage of EPOR relates the closure mechanisms to the broader culture, thereby contextualizing them (Pinch & Bijker, 1984).

These stages underpin the SCOT framework. In fact, the SCOT framework can be seen as simply an extension of EPOR into a technological context. In the SCOT model, the "developmental process of a technological artifact is described as an alternation of variation and selection" (Pinch & Bijker, 1984). This is the outworking of interpretative flexibility in its new context, as technological inventions are socially constructed and interpreted. Flexible interpretation can also lead to differences in design. A designer might tailor his product to meet the desires of certain groups and not others, or seek to tailor their desires to his/her product (Pinch & Bijker, 1984). This interaction is crucial to understanding the SCOT framework. The social context the technology exists in contributes to a diversity in technology. This creates the need for a multidirectional model to retrace the development of technology rather than a simple, step-by-step linear model. A multidirectional model will later be developed.

The multidirectional model inevitably leads to an important question: Why did the technology evolve the way it did? Or as Pinch and Bijker (1984) put it, why did "some of the variants 'die', whereas others 'survive'?" Here, it is important to remember that social groups give technology meaning. Different variants of technology have different meanings to various social groups. These social groups also have differing problems, and the solutions to these problems may be diverse. Moreover, the solutions need not be only technological but can also be social and moral (Pinch & Bijker, 1984). The function of closure mechanisms is to gradually eliminate the problems of distinct social groups. To do this, it is important to identify the relevant social groups and their agendas, values, problems, and potential solutions. This knowledge will in turn help us to understand past and possibly predict future development of the technology or industry.

This framework is especially relevant to the spacecraft industry as there are a myriad of players with varying motives, power, and capabilities. Analysis through this framework is especially relevant today as emerging companies like SpaceX, Virgin Galactic, and Blue Origin reinvent spaceflight and set new frontiers. The most important actors in this industry are private firms, the U.S. Government, high-ranking U.S. officials, science communicators, and scientists/academics. An understanding of the social network among these actors and meaning they ascribe to varying spaceflight technologies will help explain the development of spaceflight in the 21st century U.S. To contextualize these actors, a brief history of spaceflight in the U.S. is necessary.

Historical Background

Spaceflight in the U.S. has largely been restricted to the public sector since its inception. Human spaceflight, prior to the 21st century, has only occurred in the public domain. In 1958, the National Advisory Committee for Aeronautics was transformed into the National Aeronautics and Space Administration (NASA). This was in response to the Soviet Union's launching of its Sputnik satellite a year earlier, marking the beginning of the Space Age. Following the creation of NASA, there was an increase in government spending on human spaceflight with the advent of the Apollo Program in the 1960s (Weinzierl, 2018). The success of the program (landing humans on the moon) established a centralized space industry in the U.S. and led to NASA determining strategy and market structure for the industry (Weinzierl, 2018). This was not by accident: NASA Administrator James L. Webb "believed that national space policy should not be turned over to private firms. It was the government acting in the public interest that had to determine what should be done, when it should be done, and for how much money" (Bromberg, 1999).

The first entrepreneurial space enterprises emerged in the early 1990s due primarily to advances in computer and material sciences, enabling companies to build spacecraft independently of NASA (Valentine, 2012). As these firms began to become larger, they were collectively known as "New Space" (Weinzierl). NASA's 30-year Space Shuttle program ended in July 2011, and was not renewed. This was not a shock to anyone; the Obama-appointed Augustine Commission's stated in 2009, with regard to the Shuttle program, that "[I]t is… time to consider turning this transport service over to the commercial sector" (Valentine, 2012). On June 4, 2010, the SpaceX Falcon 9 rocket was launched successfully for the first time, and six months later on December 8, 2010, SpaceX did it again, this time carrying its Dragon space capsule, designed to eventually carry humans. On May 25, 2012, the Dragon docked with the International Space Station (ISS), which was the first time a commercial firm had ever done this (Valentine, 2012). An analysis of the actors and their values, interests, problems, and solutions will help shed light on the pressures that shaped the U.S. spaceflight industry.

Analysis

Companies in the private sector (viz. private companies) are composed of investors that desire a positive return on their investment. To achieve this, private companies compete for prestige and profit. For this to happen, there must be a relatively free market economy – that is, government regulation must be partially restrained. These companies may exist in a command economy, though there is no competition and the definition of what a 'company' is comes into question.

Somewhere in between a completely free market economy (no government regulation) and a command economy lies the U.S. Space Industry. The industry initially was (relatively) closer to a command economy than to a free market economy, but that has changed with time. Advances in spaceflight technology could not have been enough to radically reorient the industry. Then, the question remains: how did this occur?

NASA was formed to provide “public goods such as national security, national pride, and basic science” that are “typically underprovided if left to the market” (Weinzierl, 2018). The probability of a spaceflight market forming and providing some of these public goods in the 1960s was low, given the level of science at the time (Weinzierl, 2018). The primary way NASA seeks to provide these public goods is by asserting U.S. aerospace superiority. This is primarily accomplished via advances in unmanned and manned spaceflight.

Despite its success with the Apollo program, NASA had trouble garnering public support for its projects (Weinzierl, 2018). Apollo 11 Astronaut Buzz Aldrin lamented that “after the Apollo lunar missions, America lost its love of space – there was no concentrated follow-up and we didn’t have any clear objectives” (Sunyer, 2014). One solution NASA explored to remedy this lack of direction was the Space Transportation System (also known as the Space Shuttle program) which was designed to carry “large payloads to… the ISS, provid[e] crew rotation for the space station, and perfor[m] service missions on the Hubble Space Telescope” (Space Shuttle Program, 2022). Initially, this new direction was successful. Over time, however, the Shuttle proved to be more expensive and underperforming than expected. Catastrophes with the Challenger in 1986 and the Columbia in 2003 diminished support for the program (Weinzierl, 2018). In 2011, John Logsdon wrote “[I]t was probably a mistake to develop this particular space shuttle design, and then to build a future U.S. space program around it." The program was retired in 2011 under the Obama administration.

Why did this program fail? Was it due to poor engineering, bad management, or a general lack of public support? The answer may be more complex. Matthew Weinzierl (2018), Professor of Business Administration at Harvard Business School, believes the seeds of failure were planted when NASA established a centralized model for the industry at its inception. The failure of the Shuttle Program resulted from the manifold vulnerabilities of centralized control. These vulnerabilities include "weak incentives for the efficient allocation of resources, poor aggregation of dispersed information, and resistance to innovation due to reduced competition" (Weinzierl, 2018). Additionally, "NASA's funding and priorities were subject to frequent, at times dramatic, revision by policy makers, making it hard for the space sector to achieve even the objectives at the center" (Weinzierl, 2018). While this latter point is not directly related to centralization, it certainly exacerbated the pitfalls of centralized control.

The obvious solution to centralization is decentralization. It is clear from our previous discussion that private firms favor a less centralized market. Though NASA was initially in favor of a centralized market, their experience over the 20th and beginning of the 21st century shifted their opinion. In a history of NASA, Lambright (2016) writes that NASA administrator Michael Griffin's "vision was to build a commercial space industry" through the establishment of public-private partnerships. Additionally, other participants in the spaceflight industry including top U.S. Government officials, such as the Reagan and Obama administrations, pushed for further decentralization of the market. This alignment of goals by three of the most important players in this socio-technological network (private firms, NASA, and top U.S. Government officials) allowed and hastened the commercialization of the space industry.

Though the focus of this essay is on development and advocacy for spaceflight in the 21st century, full comprehension requires a discussion of preceding events in the 20th century. In 1962, Congress created COMSAT with the Communications Satellite Acts of 1962, a corporation owned by private investors and major telecommunications companies. This corporation was created to "leverage the expertise of NASA to jump-start a private communications satellite industry" and ultimately "led to the rapid deployment and use… of the vast array of satellites that dominate the space economy today" (Weinzierl, 2018). This public-private partnership is important as it served as a model for similar future partnerships and created a vision for the future of the space industry.

The most important development for the decentralization of the industry was the introduction of a set of public-private partnerships by Congress in 2005 called Commercial Orbital Transportation Services (COTS). This built on the previous model of COMSAT but also paved new roads in showing how a decentralized space industry could work in the 21st century. Congress funded COTS with the aim of "challenging private industry to establish capabilities and services that can open new space markets while meeting the logistics transportation needs of the International Space Station" (Weinzierl, 2018).

The genius behind COTS was that it made "NASA a customer and a partner, not supervisor, of its private contractors" by restructuring the contracts between NASA and the firms (Weinzierl, 2018). It did this by replacing "convention cost-plus procurement for customized products with fixed-price payments for the generic capabilities of delivering and disposing or returning cargo and transporting crew to low Earth orbit" (Weinzierl, 2018). This effectively placed the majority of the risk on private firms instead of NASA, incentivizing them to perform their tasks in an efficient, cost-effective manner to earn the contract. This spurs innovation on the part of the firms to produce and deliver the best product possible (e.g., Elon Musk successfully developing reusable spacecraft). For their part, private firms welcomed this new, capitalistic approach. They were given freedom to explore and pursue different competitive strategies to help them capture this newly created value (Weinzierl, 2018).

The trend did not stop with COTS. The retirement of Shuttle Program in 2011 created a vacuum for New Space companies to fill, encouraging the establishment of more public-private partnerships. NASA, at this point, had seen the value of these partnerships and has not looked back since. New Space firms thrive have thrived in the newly decentralized market and perform a wide variety of services, such as “Space access,” “Remote sensing,” “Satellite data access and analytics,” and “Habitats and space stations” (Weinzierl, 2018). Moreover, the success of the decentralizing the industry can be seen in the revenue growth from “less than $200 billion in 2005 to more than $300 billion in recent years” along with many other landmark achievements mentioned above (Weinzierl, 2018). Just five years ago, Congress passed the NASA Transition and Authorization Act. This act gives commercial firms a large amount of freedom with respect to activities in LEO. This allows NASA to focus more on research and space exploration. It seems as though NASA is content and even excited to cede direction to commercial firms so they can focus on “the public goods that have long been its core competencies” (Weinzierl, 2018).

In addition to NASA and private firms, top U.S. officials have also advocated for improved spaceflight capabilities by pushing for decentralization. We saw previously how the Obama-appointed Augustine Commission recommended further decentralization of the space industry in 2009. However, this move was presaged by the Reagan administration. In a study of the Reagan administration’s space commercialization policies, Levine (1985) found they worked to accelerate “the day when competition and deregulation will be the hallmarks of civilian operations in space." In 1984, Reagan declared, "one of the important objectives of my administration has been, and will continue to be, the encouragement of the private sector in commercial space endeavors" (Weinzierl, 2018). Additionally, during the Reagan administration the Office of Commercial Space Transportation in the Department of Transportation and the Office of Commercial Programs at NASA were created.

This is not to say Reagan (or Obama) supported these initiatives for their own sake. Top politicians in the government often seek to increase their base of political support through the passing of certain policy; in this case, it happened to be space policy. For example, Presidents Obama and Trump both favored ambitious manned space missions at a time when popular demand for it was high (Wang, 2017). According to a *Wall Street Journal Reporter*, the Trump administration admitted as much, saying they favored projects that could "attract widespread voter support" and that were achievable in his initial term (Pasztor, 2017).

Other parts of the U.S. government like the Department of Defense (DOD) are closely involved with the commercialization of the space industry. Their interest, like NASA, is mainly national security. Defense policy expert Audrey Schaffer details how the national security community is beginning to "recognize that having a vibrant commercial sector that can compete internationally will bring not just economic benefits to our country, but actually national security benefits to us because we will be able to take advantage of these new technologies, of these new capabilities" (Censer, 2016). Though there may be "a little bit of a visceral reaction against some of these [technological] capabilities that previously… were really only the province of government, of military," with the correct "policy and regulatory perspective," decentralization may be a huge boon to national security as the products these New Space firms provide serve as novel solutions to existing problems (Censer, 2016).

This process of decentralization has found additional support from private firms for another reason: the preservation of the human species. It is crucial to understand that for many (perhaps even the majority of) New Spacers, profit is simply a means to an end, summarized in the title of an Elon Musk article in 2017: “Making Humanity a Multi-Planetary Species.” As Professor of Anthropology at the University of Minnesota David Valentine puts it, “New Space is united by a common vision of the future and of capitalism: that entrepreneurial activity will radically and positively transform the future evolution of society and of our species itself by establishing human settlements in the solar system and beyond” (Valentine, 2012). Profit matters insofar as it allows spaceflight activities to continue. As Musk (2017) puts it, “we must bring in more money than we spend otherwise we’ll go out of business, but maximizing profitability is absolutely not something I care about.” This is why many New Spacers care about decentralization: “if there [are] no new entrants into the space arena with a strong ideological motivation, then it [does] not seem as if we [are] on a trajectory to ever be a space-based civilization” (Musk, 2017). For New Spacers, decentralization will help bring about “a large-scale, largely self-sufficient, developed space economy” which will aid in the ultimate goal of sending humans to other planets (Weinzierl, 2018). This is because, as Musk (2017) points out, getting people to Mars will happen only by making the cost of traveling to Mars inexpensive.

Some New Spacers believe the current decentralization policies do not go far enough. After speaking with a great many of them, Valentine (2012) remarks that “for [some] New Spacers, NASA is a wasteful government ‘jobs program,’ designed not to open up a free-market space frontier but to protect Earth-bound political and economic interests.” For them, the very existence of NASA is contrary to their ideological space civilization. A potent response from NASA supporters, Elon Musk himself being one of them, is that while the government is indeed heavily involved in the industry, it is because it regulates and creates markets in a way no one else can (Musk, 2017). One needs only to point to the history of the U.S. space industry to show this. Valentine (2012) notes that this rationale is reflective of the “neoliberal idea that ‘government’ in capitalist and libertarian models is reduced to an enabler of private citizens’ and corporations’ economic objectives, with social good emerging from the activities of private actors.”

This last point relates to a very different set of objections to the New Space vision. These objectors claim the New Spacers are truly only pursuing profit, that the honorable and virtuous façade of preserving humanity among the stars is just that – a façade, a sham. These opponents view New Space activities as simply another manifestation of the evil and greedy capitalist system. Valentine (2012), however, disagrees with these critics: “if we accept the argument that the market, or profit motive, are the only explanatory frameworks for these activities, we ignore other central and consequential aspects of the utopian visions at the heart of New Space endeavors.” This altruistic desire on the part of New Spacers must be considered, even if they are also or even primarily motivated by profit, or we risk misunderstanding and potentially harming the development of the spaceflight industry.

Other important advocates for spaceflight are science communicators and academics/scientists. Science communicator Neil deGrasse Tyson frequently hosts New Spacers like Elon Musk on a radio program called StarTalk to spread knowledge about the universe (Tyson is an astrophysicist) and spaceflight developments. Tyson contends that scientific literacy is essential to the survival of democracy (Science Network, 2011). Science communication, Tyson argues, can then be “in the service of civilization,” leading to a better society for all individuals (StarTalk, 2017). Then, Tyson shares a sort of anthropocentric altruism with the New

Spacers. Tyson advocates for increased scientific literacy so that political change can be instituted to bring about this envisioned utopia, and one he achieves this is by talking to a popular audience about spaceflight technology and developments.

Through their work, academics/scientists contribute to these broad ideological visions, but they are seldom driven by them. The Pew Research Center asked working Ph.D. scientists in 2014: "What were the one or two most significant experiences influencing your decision to become a scientist?" (Pew, 2016). Only 8% responded in the category, "to make a difference, contribute to society" (Pew, 2016). A plurality of the answers was in the category "an intellectual challenge, lifelong curiosity, love of science or nature" (Pew, 2016). However, Steele and Rickards (2021) argue that academics are "targets for and enablers of change," exemplifying "the sort of approaches and impacts they want to engender" whether they like to or not. Wilkinson (1994) adds that universities "have been forces for progress since their formation," serving "as sanctuary for cultivating the creative imagination" and as "a provocateur of new aesthetics, beliefs, and codes of conduct." Then, academics/scientists who push for increased funding for and application of aerospace research must work to promote and maintain a culture of scientific expertise and passion. The empirical data on whether or not academics/scientists have been able to successfully promote human spaceflight through the cultivation of a scientific-minded culture is scant. It is clear, however, that many leading academics have joined the spaceflight industry and made a huge impact (e.g., Dr. Michael Griffin, Dr. James Fletcher, etc.).

Discussion

As we can see, the actors in the spaceflight industry have a wide variety of values, interests, problems, and solution. To achieve a better understanding of why the spaceflight industry developed the way it did, a multidirectional view of the developmental process of the industry was created (Figure 1). It must be noted that while this map is a direct extension of the SCOT framework, it is not a map of the developmental process of a *technological* artifact but rather of an entire industry. This view will help us better understand the social network that defined the industry and led to some solutions being chosen over others.

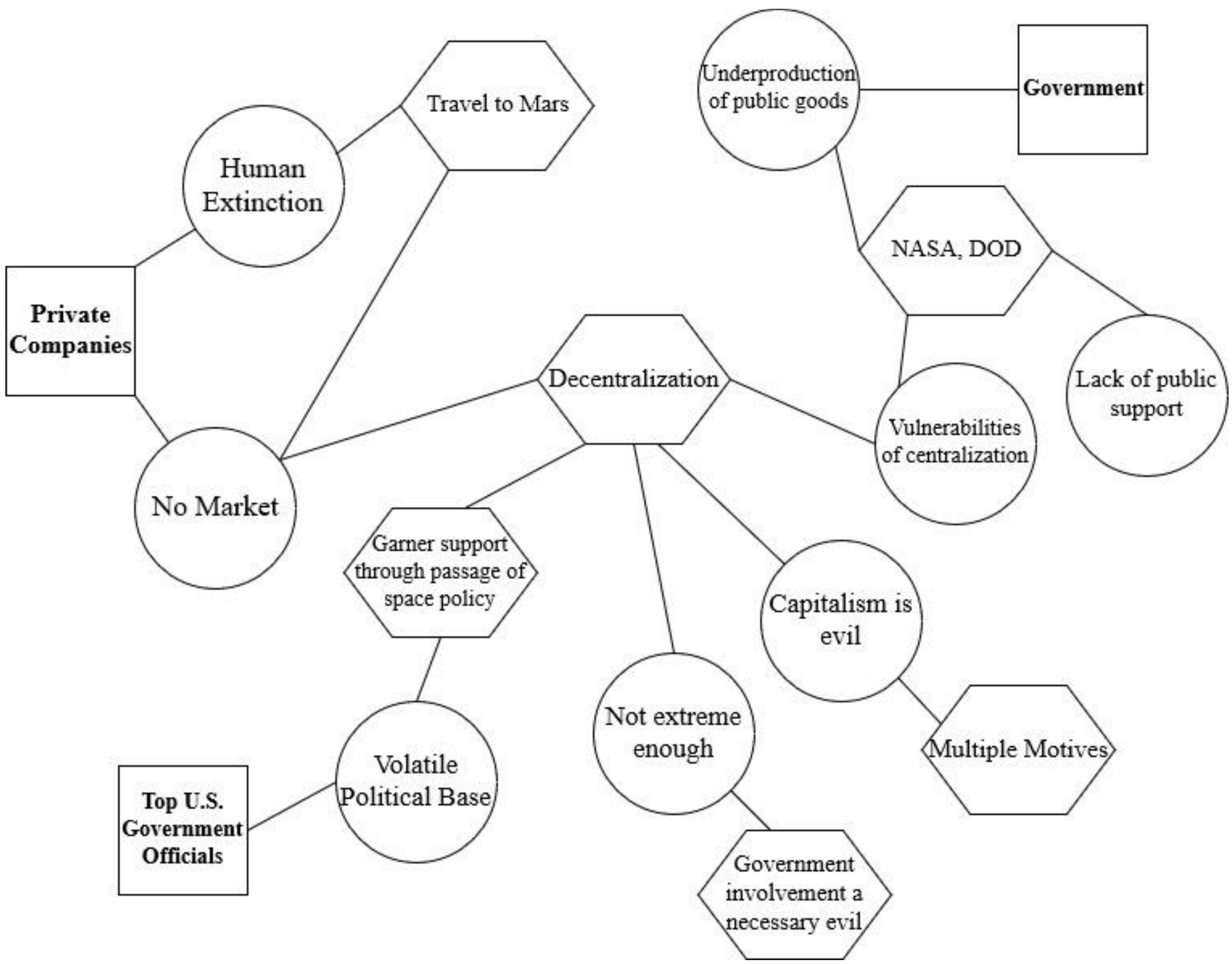

Figure 1: A multidirectional view of the spaceflight industry in the late 20th century and early 21st century. Squares represent participants, circles represent problems, and hexagons represent solutions.

This multidirectional view of the industry is by no means exhaustive but captures to a large degree the various tensions between social groups and their values, interests, problems, and solutions. The visual structure of the diagram helps show how decentralization is a common and shared solution for all of the players involved, even if it inevitably leads to some opposition from anti-capitalists or libertarians (represented by the problems “Not extreme enough” and “Capitalism is evil”). These problems are not confined to any one social group (though they may be predominately located in one) which is why they are not explicitly linked to one.

Important to note is how both of the main problems of private firms lead to the single solution of decentralization. This may manifest itself in private companies pushing more vehemently for this outcome than other social groups, as they are affected most by it. Alternatively, top U.S. Government officials and the U.S. government need not be constrained to their solutions. NASA and DOD could continue to be inefficient and fall behind by maintaining centralized control of the industry, even if this greatly stymies the production of public goods such as national security. Presidential administrations could withdraw their support when demand for space activities is low. However, over time, the cost of maintaining centralization proved to be high (with respect to the participants’ interests), which is why the U.S. Government favored a decentralizing approach.

In stage two of the SCOT framework, closure mechanisms stabilize certain solutions by eliminating or resolving certain problems. Applying this to Figure 1, we can start to envision where the industry is headed. It is clear that decentralization will occur, given how common a solution it is to all the groups involved. Other problems could foreseeably be resolved in the near future. Consider again the clear example of interpretative flexibility (different views of the same phenomena) in the anti-capitalist and libertarian oppositions to decentralization. It seems the response “government involvement is a necessary evil” is a more than adequate response to those espousing a libertarian view of absolutely no government involvement.

Instead of solving the problem, the solution to the anti-capitalist problem “Capitalism is evil” is to make the problem a non-issue, a sort of rhetorical closure. This is done by not dismissing this claim but by asking its proponents why it is being pursued (is it just capitalism?) and to consider the consequences of such a pursuit instead of outright dismissing it because of ideological bias. These problems, then, seem to be satisfactorily dealt with and thus can be eliminated, which is an outworking of closure mechanisms on the initial interpretative flexibility of the “decentralization” solution.

Conclusion

In this essay, the importance of spaceflight was delineated. Attention was given to how its advocates have pushed their agendas in the 21st century, but not in ignorance of key developments in the preceding century. The Social Construction of Technology framework contributed to a better understanding of the dynamic interplay between relevant social groups, existing technology and industry structure. Major social groups involved in the industry were analyzed to discover their values, interests, problems, and possible solutions. A multidirectional view of the industry was created to help shed light on the development of the industry. Future discussion might consider the ethics of the major participants and potential problems and solutions in the future of the industry.

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