Actor Network Theory Analysis of SpaceX's Success in the Space Industry

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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

After the space shuttle program ended in 2011, the National Aeronautics and Space Administration's (NASA) involvement in space travel declined significantly which facilitated the rise of private companies in the space industry. SpaceX has emerged as a leader in space travel with 61 successful rocket launches in 2022; other launch providers in the US combined for a total of 17 launches that same year, with NASA only completing 1 successful launch (Witze, 2023).

Most people often attribute SpaceX's rise to fewer roadblocks with funding and the organizational decline of NASA that occurred after the Apollo era (Bockel, 2018; McCurdy 1991). There exists little discussion, however, of the role international relations and concerns with state funding had with the growth of SpaceX. If these factors are overlooked, then readers will have a lack of understanding of the effect foreign affairs and congressional voting can have on technological advancement in the United States.

To assess the rise of SpaceX in the 21st century, I use actor-network theory (ANT) to argue that international relations between the United States and Russia and concerns with state funding that influenced congressional voting were dominant actors that propelled SpaceX to the top of the space industry. Actor-network theory is a theoretical framework that aims to understand how human and non-human actors interact to shape each other's actions and behaviors (Callon, 1986). Specifically, I demonstrate that SpaceX was able to respond to a need in the US space industry that developed as the Space Shuttle program ended, and it was able to respond to this need in a better way than other organizations. To do this, I evaluate news articles that discuss US-Russian relations and NASA financial documents.

Literature Review

An abundance of research exists analyzing the causes of NASA's decline and how private companies were able to rise in the industry. Most of this research focuses on NASA's financial constraints, or lack thereof in companies like SpaceX, or organizational issues in NASA caused by changing priorities as the company became more bureaucratic, as demonstrated by the following analysis. This fails to consider the effect international relations and the concerns over state funding had on the case.

In his journal article, *Space, the Final Economic Frontier,* Matthew Weinzierl highlights the major changes in the space industry since the Apollo-era. One of the primary changes he identified was the decentralization of the space industry in the 21st century caused by economic barriers NASA faced. In the mid-1960s, NASA garnered more than 0.7 percent of the GDP. Currently, NASA's budget is only around 0.1 percent of the GDP. According to Weinzierl, the Apollo missions were related to the competition with the Soviet Union; when these missions were completed, NASA's budget became vulnerable. When NASA began work on the Space Shuttle program, the cost of this program was higher than anticipated and it performed much weaker. After the Columbia disaster, NASA's funding was subject to frequent and dramatic revision by policymakers. When the Space Shuttle program ended in 2011, reformers in the private space sector seized their opportunity. Where NASA relies on Congress for its funding, these New Space companies were funded by high-profile entrepreneurs. According to the journal article, "outside investment in start-up New Space firms has risen from less than $500 million per year from 2001 to 2008 to roughly $2.5 billion per year in 2015 and 2016". Thus, New Space companies were able to overcome the economic hurdles that NASA faced, allowing private companies to become prominent in the industry (Weinzierl, 2018).

In his journal article, *Organization Decline: NASA and the lifecycle of bureau*, Howard McCurdy explored various factors that contributed to NASA's decline in the post-apollo era. Particularly, the journal focuses on budget cuts, increasing bureaucracy and conservative values in management. Due to a lack of public support for the space program after the Apollo missions, recommendations for an ambitious space program to maintain space activities were rejected. This is not where the effects of the lack of support ended, however. Between the height of the Apollo program to 1989, the total number of NASA employees fell by 12,000 and the total appropriation fell by almost $8 billion. As this occurred, the organization became more bureaucratic in the sense of "excessive paperwork and a preoccupation with official procedures". When NASA was formed, the organization placed a greater emphasis on "hands-on" work over "paper pushing and official procedures". As the lunar expeditions began, NASA was required to contract out most of its work due to the small size of its workforce. McCurdy also explored the effects of the organization becoming more conservative at the management level. The Apollo generation observed that NASA's management was dominated by people who "are cautious and inclined to avoid risks". McCurdy indicated that although overall opportunities for promotion fell dramatically, professional administrators, or those engaged in financial management, procurement, personnel administration, law, and public affairs, were twice as likely to receive a promotion as NASA scientists and engineers. This demonstrates that NASA shifted its emphasis to system maintenance from the values of science and engineering, which was the initial emphasis of the organization (McCurdy, 1991).

The journal published by Weinzierl identifies the reduction in economic barriers as being a primary reason as to why private companies were able to rise in the space industry. Similarly, the journal by McCurdy recognizes the funding cuts as public interest depleted as being a cause

of the eventual decline of NASA. Due to slashes in funding and hiring, NASA had to contract out most of its technology; this required more oversite and paperwork for the NASA employees. While these factors did contribute to SpaceX's ability to rise in the industry, these documents fail to explore the contribution international affairs and state funding concerns had on this case. I believe poor relations between the United States and Russia was the root cause of SpaceX's lack of financial constraints as the company continued to develop. This was overlooked by both of these documents, and it is a key factor is understanding why SpaceX was able to develop as fast as it did. Further, although the second article demonstrated how lack of public interest resulted in budget cuts from congress leading to NASA's decline, this article failed to observe that growing concerns over NASA's declining influence ultimately led to the privatization of the space industry and SpaceX's escalation.

Conceptual Framework

Actor-Network Theory (ANT) is a science, technology, and society (STS) framework that provides an effective method to analyze SpaceX's growth because it allows me to analyze the various factors that contributed to the development and preservation of this network. ANT is a methodology for studying the relationships and interactions between human and non-human actors that are recruited by a network builder to accomplish a specific goal (Callon, 1987). Actors within these networks are not seen as fixed entities but are instead constantly evolving and influencing other actors in the network. Sociotechnical systems develop through negotiations between these various actors, such as people, institutions, and organizations, and since the actors are constantly developing, the networks also constantly evolve (Cressman, 2009). According to ANT, each actor is composed of its own network, but it relies on the overarching or higher-level network to remain stable. Thus, individual actors are not inherently powerful, but their power

arises from their relationships with other relevant actors. The strength of these relationships is what creates the power in an actor-network, rather than the strength of each independent actor (Latour, 1986).

In this paper, I will follow the interpretation of ANT developed by French sociologist Michel Callon, with a focus on his concept of translation, which is the process of creating and maintaining an actor-network. Callon identifies four phases of translation: problematisation, interessement, enrolment, and mobilisation (Callon, 1986). During problematisation, primary actors identify a sociotechnical problem followed by the human and non-human actors who are required to accomplish the goal. The primary actor sets itself as the "obligatory passage point" (OPP through which other actors must pass to form a stable network. In the second step, interessement, the primary actor attempts to recruit other actors into the network. This may include persuading actors to leave previously established networks. In enrolment, the primary actor assigns roles and positions to the other actors that have aligned with the problem definition. Callon details that it is required for these other actors to accept and faithfully carry out their assigned roles as intended during the enrolment stage. In the final stage, mobilisation, the primary actor secures its role as the representative and spokesperson for the remaining actors. It is at this point that the actor-network begins to function cohesively.

Since the power in an actor-network relies on the association between actors, actor-networks may not always remain balanced. This balance can be interrupted if relationships between actors begin to fail or if objectives between the primary and remaining actors begin to differ. If this occurs, the legitimacy of the spokesperson becomes challenged, new translations occur, and the network becomes unstable (Silva, 2019). I will use Callon's ANT framework to analyze success within an actor-network that led to the growth of SpaceX. Callon's concept of

translation will allow me to identify how this actor-network formed relationships between actors that were previously part of unstable actor-networks.

Analysis of Evidence

Network Formation

To begin analyzing the success of the SpaceX actor-network, it is important to analyze how the network formed, which begins with identifying key human and non-human actors. Human actors include NASA; investors; engineers who were responsible for the development of the technology; competitors, such as other private companies in the industry; the US government; and international governments, particularly the Russian government. Integral non-human actors include: the infrastructure, such as manufacturing and launch sites, money, and the technology, such as the rockets and capsules.

According to Callon's theory of translation, a primary actor must be designated through which all other relationships are dictated (Callon, 1986). In accounts of the company's history, all decisions directly dealing with SpaceX came through the founder, Elon Musk. Although engineers within the company are responsible for designing and manufacturing the products, Musk spends most of his time with the engineering teams making decisions on how to improve the spacecraft and develop the Mars Colonial architecture (Cao, 2021). Therefore, in this paper, I will assume that

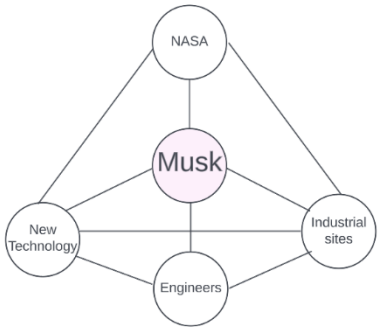

Figure 1: SpaceX's actor-network. Primary actor (Musk) shown in red, secondary actors shown in white.

Elon Musk is the primary actor around which SpaceX is formed and maintained.

To complete the first step of the translation process, problemization, Musk had to determine a goal to be accomplished. At the time when SpaceX was founded in 2002, it had been 28 years since the last crewed mission to the Moon. The goal Musk identified was to make humanity multiplanetary, thus, the company was established to create a permanent settlement on Mars (SpaceX, n.d.). After the primary goal was established, Musk developed a secondary goal to bring down the cost of exploration which was to have “frequent, more reliable launches” (Howell, 2022a). Based on this, Musk identified that engineers were needed to develop the technology, manufacturing sites were required to test and manufacture the technology, and that money was required to fund this innovation. When the company was founded, funding was not easy to come across, primarily because the space industry is extremely high risk. Musk was able to fund this goal himself initially and invested $100 million to maintain the company (Howell,2022a). However, to ultimately bring down the cost of exploration, he “sought out a stable customer that could fund the early development of a rocket: NASA " (Howell, 2022a). As illustrated in figure 1, Musk laid out the network by connecting the other human actors around himself at the OPP.

During interessement, Musk had to recruit these other human actors into the network by aligning their interests to the problem definition. He first recruited engineers who will design and develop the technologies and who will readily take a risk. One of these first engineers who were recruited was Tom Mueller, who became the chief technology officer of propulsion at SpaceX (Clifford, 2019). Next, Musk had to recruit customers who were interested in the technology, particularly NASA. To do this, Musk had to prove that he could make a successful, affordable spacecraft. Falcon 1 was the first rocket developed by SpaceX and was designed to provide the

world's lowest cost access to orbit with high reliability (Dinardi & Bjelde, n.d.). During the initial development of this rocket, SpaceX received $278 million from NASA under the agency's commercial Orbital Transportation Services (COTS), which was created to spur the development of systems that could transport cargo to the ISS. As shown in figure 2, the Falcon 1 rocket could launch at a much lower cost per kilogram than the Space Shuttle developed by NASA (Fox, 2018). In September 2008, SpaceX's Falcon 1 rocket launched successfully and achieved Earth orbit after 3 failed attempts (NASA, 2008). This successful demonstration of affordable spaceflight led NASA to award SpaceX with a contract for 12 commercial resupply flights to the ISS (Howell, 2022a). This completed the interessement stage of translation now that all the actors identified by Musk were aligned with the problem definition.

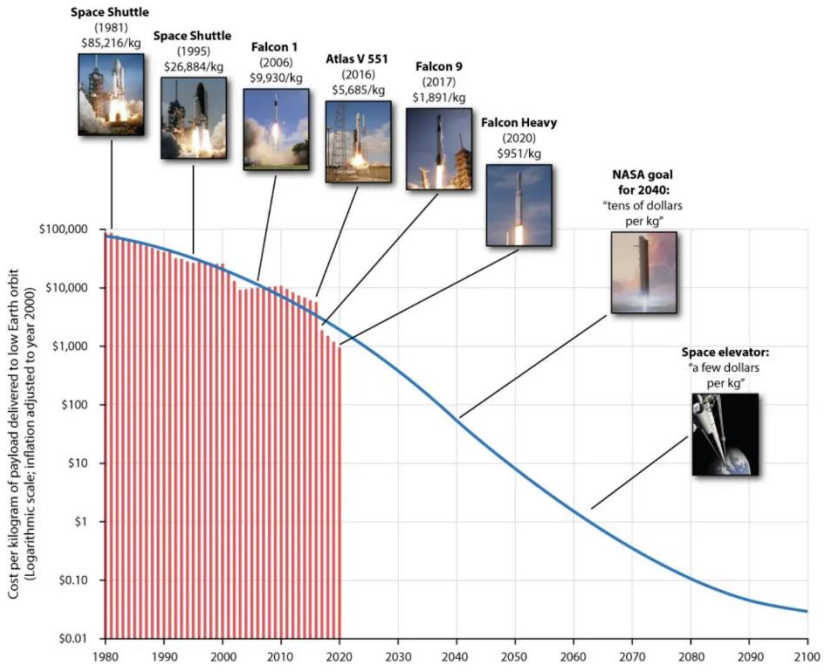

Figure 2: Cost per kilogram of SpaceX's Falcon 1 rocket compared to the Space Shuttle

Success of Enrolment

Tensions between the United States and Russia are often overlooked; however, this was crucial to the success of the enrolment stage of translation as it facilitated the human actors accepting their allotted roles, primarily for NASA being a stable customer to SpaceX. In 2004, President George Bush announced the end of the Space Shuttle program. When the program

officially ended in 2011, NASA became dependent on Russia for access to the ISS, since the only reliable method to get American astronauts to space would be using the Russian Soyuz Capsule (Howell, 2022b). This cooperation between the US and Russia did not come without risk and most Americans identified this. In the same year the space shuttle program ended, Putin's United Russia party won the parliamentary elections resulting in massive protests throughout Russia over claims of vote-rigging. Hillary Clinton, who was Secretary of State in 2011, expressed concerns over the voting and called for a "full investigation" into the irregularities (Labott, 2011). Putin, outraged by these comments, issued the following statement:

> We are a big nuclear power and remain so. This raises certain concerns with our partners. They try to shake us up so that we don't forget who is the boss on our planet, so that we obey them and feel that they have leverage over us inside our country. (...) We need to work out ways to protect our sovereignty, defense against interference from outside. I looked at the first reaction of our American partners, the first thing that the [US] secretary of state did was to give her opinion about elections, she said they were unfair and unjust, even before she got [Office for Democratic Institutions and Human Rights] monitors' materials, She set the tone for some of the activists inside our country, gave them a signal, they heard this signal and started active work with support from the US state Department. Those who won the elections in fair and open struggle should work in the Duma (Elder, 2011) .

This statement was followed by significant crackdowns on US activities to promote Russian democracy. First, this speech indicates the poor relations between the two countries, primarily the feeling that the US wants Russia to "obey them" and that they have "leverage" inside of the country. This indicates that Putin felt threatened by US influence in Russia and that he sees the

United States as a threat to Russia's global influence. He states that the US influence is a threat to "Russia", but what he really means is that Clinton's concerns are a threat for his entire party that is running the country. This is further demonstrated by his final statement acknowledging that "those who won the elections (...) should work in the Duma". Despite the protests beginning before Clinton expressed her concerns, Putin views her statement as an attempt to incite the Russian people to eject all those recently nominated. He sees the United States as a power that Russia must defend itself against, and that can seem extremely unnerving to NASA who is now reliant on Russia to launch its astronauts.

If NASA continued to be dependent on Russia as tensions continued to rise, there were various outcomes that could have resulted. Primarily, if Russia wanted to exhibit its dominance over the US, who believes it is the "boss on [this] planet", it could have ended the partnership between the two countries. This would make it so NASA would lose access to the ISS until it found another reliable launch vehicle, while Russia would have uninterrupted access. If this occurred, the US would lose its presence in the space industry. NASA identified this as a possibility and decided to partner with a customer that could be more reliable in the long term: SpaceX. The contract between NASA and Space in 2008 funded the Dragon 1 capsule which was responsible for 20 missions between 2010 and 2020 to resupply the ISS. In 2014, after US-Russian tensions continued to escalate, SpaceX began developing its Dragon 2 capsule with crew and cargo capabilities (SpaceX CRS Mission, n.d.). In a statement about its contract with SpaceX, NASA said that this contract "allows NASA to maintain an uninterrupted US capability for human access to the space station until 2030"(Foust, 2022). This statement demonstrates NASA's concern in regard to continuous access to the ISS. In this statement, NASA acknowledged that the Soyuz capsule was unable to meet its needs and SpaceX was a much more

reliable launch provider. At this point, SpaceX was able to demonstrate that it could manufacture safe and reliable spacecraft, and it secured NASA's position as a stable customer to SpaceX.

I have argued that tensions between the US and Russia was a key factor that put SpaceX at the top of the space industry. Opponents to this view may argue that rising tensions was not the root cause of NASA's decision to switch from the Soyuz to Dragon 2, rather it was the lower cost associated with launching astronauts with SpaceX as compared to the Russian capsule. Yet it should be noted that there is evidence of US-Russian relations affecting their space cooperation. In 2014, the US cut Putin out of global meetings and imposed punitive measures against his team after Russia unlawfully annexed Crimea. In response to US sanctions prohibiting work with Russian aerospace companies, Dmitry Rogozin, former deputy Prime Minister of Russia for Defense and Space Industry, wrote, "After analyzing the sanctions against our space industry, I suggest the US delivers its astronauts to the ISS with a trampoline." (Koren, 2019). It was that same year that NASA signed its contract with SpaceX.

Although I established those tensions between the US and Russia is what officially secured NASA's position as a stable customer to SpaceX, it is also important to note that NASA receives its funding from congress. For the enrolment stage to be considered successful, Congress, a tertiary actor in SpaceX's actor-network, would need to support the cooperation between SpaceX and NASA and approve a budget that would be accepted by SpaceX and NASA. Figure 3 depicts SpaceX's entire actor-network, including tertiary actors. This factor,

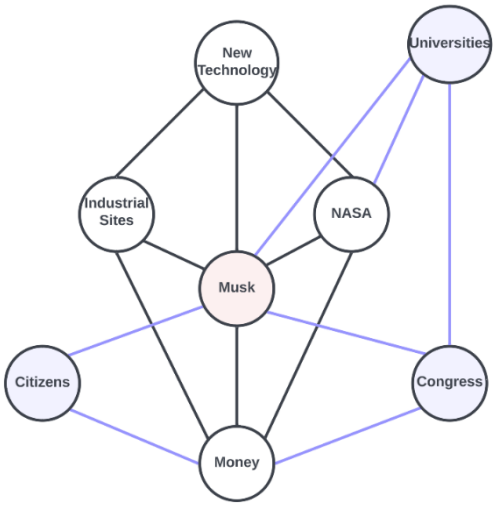

Figure 3: SpaceX's complete actor network. Primary actor (Musk) shown in red, secondary actors shown in white, tertiary actors shown in purple.

which can more simply be understood as the competition between governmental and private organizations, is also often overlooked by many who analyze SpaceX's growth, despite it being so crucial to the company.

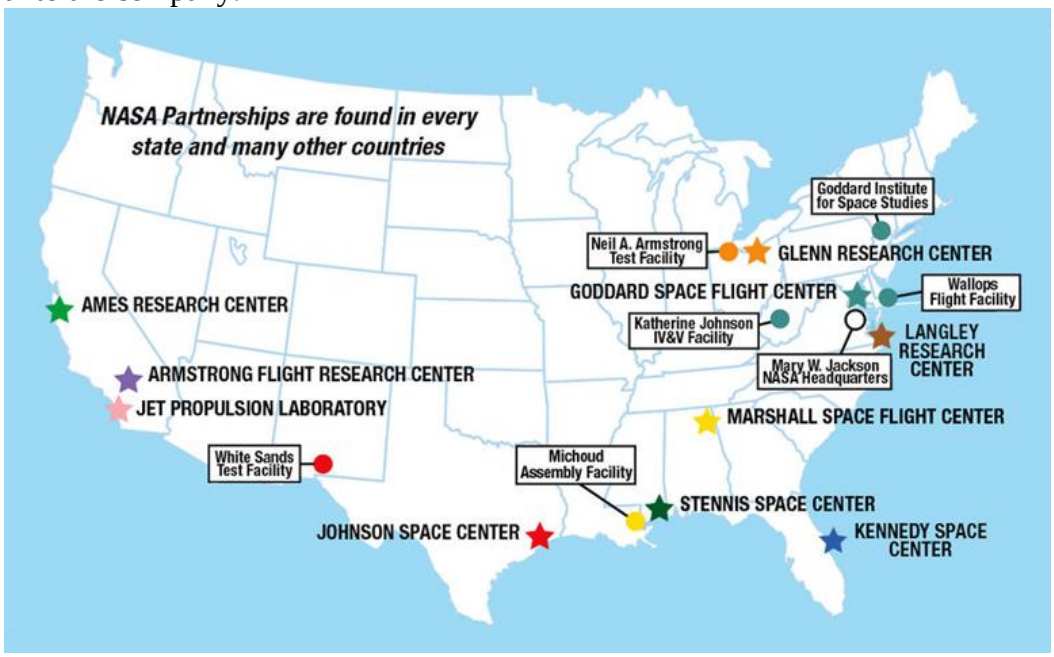

Figure 4: States with NASA locations

If the space industry started to become entirely privatized without any government involvement, states, particularly those with NASA locations, would lose the income and benefits associated with these locations. States that have a considerable NASA influence such as Alabama, California, Florida, Maryland, Louisiana, Texas, and Virginia, as shown in Figure 4, would want to maintain these benefits (Harbaugh, 2015). To demonstrate NASA's impact on its surrounding region, the Texas Comptroller report released the following statement about how Texas benefits from having a NASA location:

> NASA makes a $4.7 billion annual impact on the Texas economy and directly and indirectly supports more than 52,000 jobs. Its influence plays a critical role in the education, research, tourism and business activities in Texas' Gulf Coast Region and the state as a whole (NASA Leading a Booming Texas Economy, 2019).

This statement is vital for understanding congress' role in SpaceX's development. Texas, with only one NASA location, reaps a multitude of benefits from having a NASA center, including a $4.7 billion annual impact and more than 52,000 jobs. It would be devastating to Texas if NASA no longer existed, and the space industry was solely private. Mentioned in the quote above, there are many universities that have contracts with NASA, including the University system of Texas and the University system of Florida, that may lose these contracts as NASA's influence declines (*30* Colleges That Are Contributing to Space Exploration, 2022). Figure 5 provides more insight into why congress would have prevented the space industry from becoming solely private.

NASA Contractor	US $ million	% Total of NASA Contract funding
California Institute of Technology	$ 2,659	13.34
SpaceX	$ 2,088	10.48
The Boeing Company	$ 1,707	8.57
Lockheed Martin Corp.	$ 1,346	6.76
Northrop Grumman Corp.	$ 1,145	5.75
Jacobs Solutions Inc	$ 957	4.8
KBR Inc.	$ 720	3.61
Science Applications International Corp.	$ 443	2.22
Aerojet Rocketdyne Holdings Inc.	$ 408	2.05
Johns Hopkins University	$ 349	1.75

Figure 5: Ten highest NASA contracts in 2022

The ten highest NASA contractors in 2022 accounted for more than 59% of NASA contract funding with the top five constituting almost 45% alone (Top-100 NASA Contractors in FY 2022, n.d.). If these contracts vanish, it may have devastating effects on the states that these contracts exist in. Employees at these companies would lose their jobs, and universities would lose the funding and prestige associated with having a contract with NASA. Thus, state representatives would likely vote against any initiative that could reduce their state's funding or take away from higher education. This would entail forcing NASA to maintain its influence,

preventing the space industry from becoming entirely private, and creating partnerships between governmental and private companies. Without this partnership with NASA, SpaceX's actor-network would not be as successful because there would be no "stable customer" for the company. With Congress supporting NASA's contracts with SpaceX, SpaceX now has a guaranteed customer providing significant funding to the company for years to come.

Conclusion

In this paper, I utilized the sociotechnical concept of actor network theory to examine the factors that contributed to SpaceX's success in the 21st century. To strengthen my argument, I specifically used ANT's concept of translation established by Callon. With evidence from news articles about Russian- US relations, and documents that summarize NASA's contractors, the origin of the success of this network can be determined. Current understanding of the case dictates that lack of economic constraints and organizational decline in NASA are at the root of SpaceX's growth. However, is evident that international relations and concerns over state funding are two of the primary factors that facilitated this success. This understanding will allow readers to recognize the overarching politics at play in the space industry and increase awareness that technological advancements can be affected by domestic trends.

Word Count: 3864

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