THE SOCIAL SHAPING OF AEROSPACE TECHNOLOGY IN THE MID 20TH CENTURY

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By

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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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TECHNOLOGIES EMERGING FROM SOCIETAL CHAOS

Since 1950, the average global temperature has increased by over 0.75 °C (The Learning Network, 2020). Consequences of this warming are seen in worsening storms, heatwaves, and droughts, all of which are fuel for wildfires. Between 1984 and 2020, area burned by wildfires in the United States grew by approximately six million acres (The Learning Network, 2020). This devastation compels government agencies to increase funding for wildland firefighting. Since 2005, firefighting spending in California more than tripled and as of 2020, has surpassed three billion dollars (Beam, 2021). As wildfires grow more expensive and uncontrollable, firefighting organizations are facing more pressure to keep their communities safe from the flames. To relieve this pressure, organizations are supplementing ground fighting methods by increasing aerial firefighting through the development of new aerial firefighting technology.

The increasing threat that wildfires pose to societies around the world motivated the technical topic to design an aerial firefighting aircraft. The purpose of this work was to enter the American Institute of Aeronautics and Astronautics, or AIAA, 2022 competition to develop a responsive aerial firefighting aircraft. This challenge aims to generate momentum in developing new, competitive firefighting aircraft to replace inefficient and outdated current technology and raise technological standards while addressing the core problem of climate change. The final deliverable was a technical report, detailing a complete concept aerial firefighting aircraft and design justifications to be entered into the AIAA competition for review and ranking. Work was done under the supervision of faculty advisor Jesse Quinlan and alongside technical team members Yicong Fu, Logan Honts, Ryan Keough, Lama Khraibani, Quang Lam, Nicholas Martin, and Jaylon Williams.

Excluding a list of aircraft requirements given by AIAA, one of the primary design drivers in this project was fuel efficiency. Humankind’s overconsumption of fossil fuels is the leading cause of planetary warming (NASA, 2021). In order to not further contribute to climate change, various fuel efficient structural and propulsion elements were implemented in the aircraft’s design. Combating climate change is a current social and political value of societies across the globe. In the technical project, it influenced specific design characteristics in an aerospace innovation. This exemplifies the symbiotic relationship between societies and technology that can be understood when examined under the framework of Social Shaping of Technology (SST). While the technical topic considers climate change and its effect on the design of future aircraft, the STS thesis investigates this sociotechnical relationship in air and spacecraft of the past, seeking to answer the question of how Soviet socialist and American capitalist values influence design differences in Cold War era aerospace technology. Coupling the technical research with the STS topic allows for a deeper understanding of how social and political values directly influence technology by expanding the scope of analysis to cover the past and future.

Addressing the research question, the STS investigation began with a historical analysis of the Soviet Union (USSR) and the United States of America (USA) during the Cold War to determine the social and political values most influential and distinct in each state. Following this social analysis, comparable air and spacecraft were selected from each state and technically evaluated to find significant and contrasting design differences. Finally, these two investigations were merged, superimposing the social and political values to the technological design features. The final synthesis of these two components was done using an input/output interpretation of SST to determine which design features were influenced by which sociopolitical value.

Motivation to investigate this question stemmed from personal interest in the Space Race which resulted in the Saturn V and N1 rockets. Initial research into Cold War spacecraft eventually expanded to include aircraft, widening the scope of the investigation to cover the two main subsets of aerospace technology. The purpose of this research is to assess how societal values drive technological design through the example of Cold War aerospace technology. Because technologies are created primarily to benefit society, using SST to address this question deepen the understanding of the progression of humanity by illustrating how the two variable are connected, have influenced eachother in the past, and how they can influence change in the future.

THE DISPARITY BETWEEN SOVIET AND AMERICAN SOCIETAL INFLUENCE ON TECHNOLOGY

SST: INFLUENCERS OF AEROSPACE DESIGN

Social Shaping of Technology, a theory by Williams (1996), states that technologies are shaped by social and political values. This theory expands on Social Construction of Technology, from Pinch and Bijker (1984), which argues that humanity influences technology and that social groups create different functions of technology based on flexibility in interpretation. SST continues this claim, positing that because technology is reflective of specific sociopolitical values, differences in these values will elicit differences in technological design (Kidd, 2012). Furthermore, innovation is socially motivated and societies are responsible for how the world technologically advances. Figure 1 below depicts various factors that can influence technological differences.

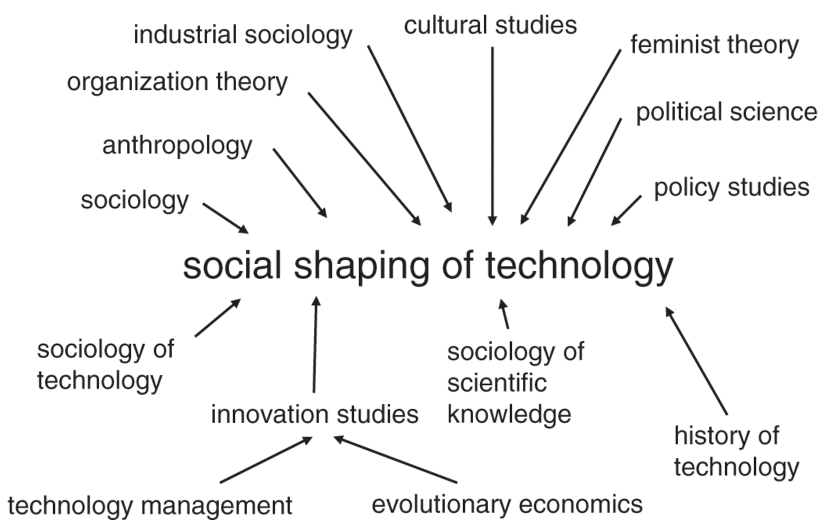

Figure 1. Inputs to SST: many factors influence technological design. (Pittinsky, 2019)

Social Shaping of Technology can be interpreted as an input/output function. Applying this to a technological artifact, a social or political value is the input, the technology is the function, and a corresponding design choice is the output. To begin applying this interpretation of SST to Cold War air and spacecraft in order understand the relationship with sociopolitical ideas is to identify the inputs from a historical analysis of the USSR and the USA.

THE COLD WAR ERA

The Cold War, from 1947 to 1991, was a period of intensity and unrest between the ideologically opposed USSR and USA (Schlesinger, 1967). This war manifested in both physical and non-physical battling with the root of all conflicts being the two states' opposing and incompatible sociopolitical values. During the Cold War, both states experienced significant transformation but in very different ways.

The Golden Age of Capitalism

In the aftermath of World War II, the USA was enjoying great economic prosperity. The country experienced growth characterized by "fast-growth, high-productivity, [and a] low-inequality economy built on a cooperative and stable relationship between Big Business management and labor," (Pethokoukis, 2020, p.1). American society operated under capitalist theory, resulting in the celebration of capitalist values including profit maximization, business competition, and corporate power. The commercial aerospace industry in the USA also experienced growth with Boeing, North American Aviation, and McDonnell Douglas expanding their products and reach (Boeing, 2021). Due to this success and stability, the time period would eventually be named the Golden Age of American Capitalism.

Post-Stalin Socialism

In the East, the Soviet Union experienced more dramatic change, transitioning from brutal Stalinism to a more modern and ideally socialist state under the leadership of Nikita Khruschev (David-West, 2008). In 1956, Khrushchev delivered a speech titled *On the Cult of Personality and Its Consequences* where he reminded his colleagues in congress of the fundamental Marxist-Leninist principles that had been lost under Stalin (Khrushchev, 1956). Khruschev reinforced the importance of these Soviet socialist values in the transition to a new society which included powerful centralized state control of production, people over profit and collectivism, and militarized defense of the state at all costs (Schlapentokh, 1984). Similar to the USA, the Soviet state-run civil aerospace industry expanded rapidly, responding to the escalating threat of war with the West. This resulted in an explosion of new air and spacecraft from the USSR that was paralleled in the USA.

COLD WAR AIRCRAFT

Both the USA and the USSR expanded their military aircraft fleets in preparation for war. This growth resulted in a cyclic trend where one state would engineer new aircraft and a response to new jets innovated in the other state. This pattern is exemplified by the Soviet Mikoyan MiG-29 jet that was engineered to compete with the American McDonnell Douglas F/A-18 ((MiGFLUG, 2016). Due to their status as direct counterparts, these aircraft were analyzed for significant design differences.

The McDonnell Douglas F/A-18

The F/A-18 is a twin engine, multirole tactical jet that was remarkably agile relative to other jets of the era (Military Advantage, 2022). It acheived this agility through wing modifications, complex avionics, and innovative electronic control systems. It was also very multipurposed, having technical instrumentation to carry out both air-to-air and air-to-ground missions as both a fighter jet and an attack jet along with several other defense and reconnaissance roles (Boeing, 2021a). This technical excellency comes at a cost, specifically around 67 million dollars as of 2021 which adjusts toapproximately 20 million in 1980

(AeroCorner, 2022). The aircraft vastly out-performed competitors in missions that required long-distance accuracy and finesse, leading to a popular sentiment of the time that, "[Americans built] airplanes like fine watches," (MiGFLUG, 2016, p.1).

The Miyokan MiG-29

The competitor in the East to the F/A-18 was the Soviet Mikoyan MiG-29. While the F/A-18 was very technical and precise, the MiG-29 was more simplistic and sturdy (MiGFLUG, 2016). The aircraft was originally designed for single use as a combat plane and later evolved to be compatible with more complex missions (Military Wiki). The aircraft opted for flight controls operated by basic linkage mechanics instead of the newer fly-by-wire controls that were growing more popular in the West. The MiG-29 excelled in close combat dogfighting (Arg, 2022). It was said to have, "unmatched flight performance with its manueverability remaining without compare," (Military Watch Magazine, 2021, p.1). This is due to its simplistic aerodynamic structural design which allowed for optimized maneuverability. Other added control surfaces such as tail flaps, ailerons, and wing modifications further optimized control. Many parts and instruments in the MiG-29 were compatible for use in other Soviet aircraft. While other aircraft utilized complex instruments to prevent disasters, the MiG-29's airframe itself was the technology responsible for recovery from in-air spins that often caused catastrophic failure (Military Factory, 2021). Additionally, the Soviet aerospace industry was civil rather than commercial, resulting in state-sponsored generic technical instrumentation (Howie, 1995). The MiG-29 typically sells for around 24 million dollars, adjusted to approximately 7 million in 1980 (Ritsick).

COLD WAR SPACECRAFT

While the Cold War era produced many notable aircraft that are still in service, it was the spacecraft of this era that facilitated one of the largest engineering successes in history. The Space Race, a high pressure aerospace engineering competition to reach the moon, produced the Saturn V and the N1 rockets.

The Saturn V

The Saturn V rocket was the largest rocket of its time and most powerful to ever fly (Day, 2016). Developed at the NASA Marshall Space Flight Center, Saturn V was composed of three stages with patterns of five and two engine configurations (Boeing, 2021b). Work on the three stages were contracted out to various American aerospace companies McDonnell Douglas, North American Aviation, and Boeing. 15 flight-capable vehicles and three ground testing vehicles in total were built. The engines on the stages were fueled by liquid hydrogen and liquid oxygen, a newer propellant type in rocket propulsion that was adopted in the 1950's.

The N1 Rocket

News of American success with the Saturn V program lit a fire beneath Soviet aerospace engineers and officials, compelling them to start development of the N1 rocket (Wade, 2019). From Wade (2019), the N1 rocket was composed of five stages. The N1 rocket, seen as the left rocket in Figure 2, was also composed of many instruments that were orignially designed for and compatible with other Soviet military applications. Additionally, the N1 rocket had thirty engines. To power the engines, a lead engineer Valentin Glushko, suggested the use of nitrogen tetroxide, a promising new oxidizer that was growing in popularity in the West. Korolev immediately rejected the idea due to his preference to an outdated propellant, LOX-Kerosene, as well as because of a personal grievance toward Glushko. The N1 program also incorporated a vast varierty of other various military capabilities such as weaponry rendevous and recoinnassance missions.

SST: INFLUENCERS OF DESIGN

Despite having access to the same information, technology, and government pressure and being designed for the same purpose, the pairs of air and spacecraft have several distinct design characteristics. Determining the reasons for these differences requires the relationship between societies and technology. An application of the input/output interpretation of SST on Cold War era aerospace technology allows for organization and visualization of this relation. Inputting a sociopolitical value into the model will output a reflective technological design element.

The Soviet Societal Influence on Aerospace Technology

Figure 2 below illustrates the relationship between Soviet society and technology through the lens of SST. The left arrows represent inputs which correspond by color and height to the output arrows on the right.

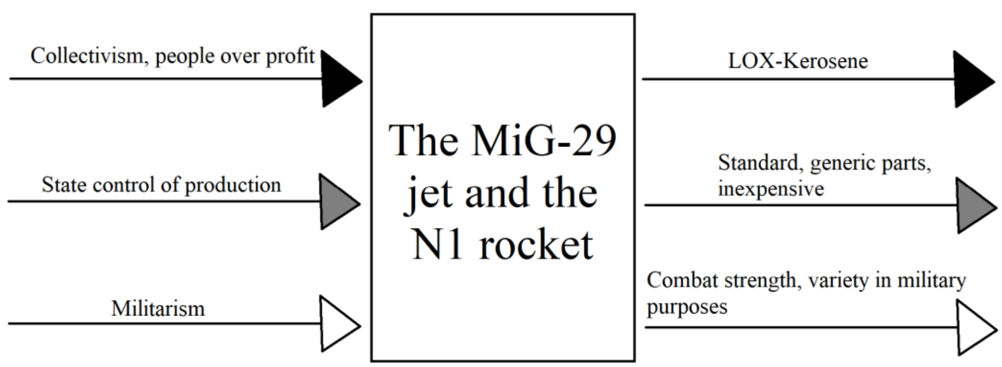

Figure 2. SST Applied to Soviet Aerospace Tech: the inputs and specific outputs (Johnson, 2022b)

The first input, collectivism and people over profit, was essential to Soviet socialist society and the design of the N1 rocket. Korolev refused the implementation of Glushko’s proposed propulsion system due to a personal grievance. This grievance stemmed from Glushko's culpability in Korolev's prior unjust sentence to a Gulag. As a loyal member of Soviet society, it was Korolev's duty to uphold the values of the State in his work. For this reason, Korolev rejected Glushko, perceiving his colleague as egotistical and his suggestion as a maneuver to gain personal glory. Korolev decided to defend collectivism and the value of people in the N1, implementing a tried-and-true propulsion system that was likely to work and benefit the larger program, engineers as one, and the State.

The second input, state control of production, had the greatest impact on the Mig-29 and N1. The Soviet aerospace industry was civil, meaning that all engineering was overseen by the state and resulting in a vacuum in variety, collaboration, and funding. There was a lack of specialized technical instruments in the air and spacecraft demonstrated by the MiG-29 and the N1 using parts that were generic rather than specially designed for the technology. State control also influenced the technologies to use outdated or manual subsystems, such as the basic linkage mechanics and the self-correcting body structure, rather than risk failure and cost with experimental innovation. Finally central power encouraged inexpensive design. No benefit would come to the state by spending more on materials, avionics, and complex structures. This value is demonstrated by the large disparity in price, over 10 million, between the MiG-29 and the F/A-18

The final input is extreme militarism. Because the Soviet Union placed so much emphasis on this value, air and spacecraft were particularly strong in this area. The MiG-29 was noticeably adept in combat due to its design that centered around optimizing simplicity and maneuverability. The many control surfaces on the MiG-29 allowed the aircraft to be supermaneuverable, optimal for close combat. Additionally, militarism influenced the N1 rocket to have added instrumentation. This instrumentation was intended to allow the rocket to carry out a long list of military missions. These additions overweighted the rocket and overcomplicated the program, ultimately leading to the rocket's catastrophic failure.

The American Societal Influence on Aerospace Technology

Figure 3 below continues the investigation of technology through the framework of SST from Soviet sphere to the American.

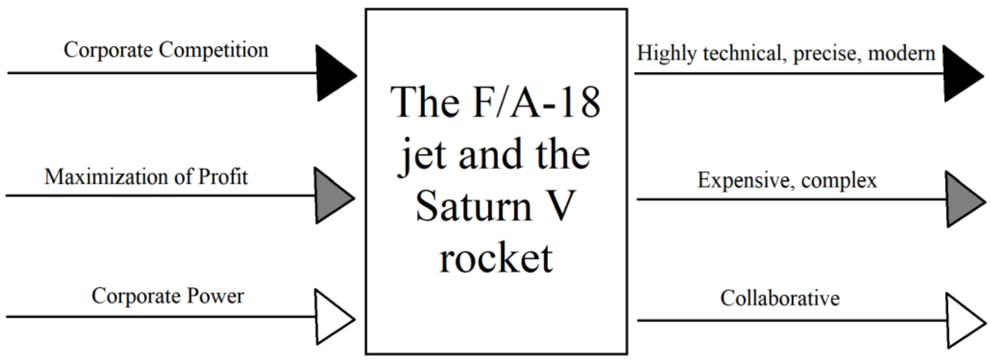

Figure 3. SST Applied to American Aerospace Tech: the inputs and specific outputs (Johnson, 2022a)

Seen as the upper left arrow, corporate competition as a sociopolitical value influenced technological design of both the the F/A-18 and the Saturn V. Because businesses needed to outperform their competition in order to succeed in the capitalist market, companies were compelled to continuously output high quality, modern, and innovative products. As a result, American aerospace technology earned the comparison to fine watches with their implementation of innovative electronics and subsystem. The F/A-18 was very technically robust exemplified by the and as a result, was designed to take on many different missions.

The second input is maximization of profit. Demonstrated in its 20 million dollar price point in comparison to the Mig-29's 7 million, design of the F/A-18 was centered around the goal of generating the most profit for McDonnell Douglas. Additionally, the jet was designed to be technically luxurious, allowing it to be sold more far greater than a simpler jet. Additionally, the Saturn V was the largest, most powerful, and most technically complex rocket ever created and flown. Reasoning that NASA would have to pay more for these features, this strategy in design was influenced by the contracting companys' desire to maximize their profits.

The final American sociopolitical input in the context of SST was corporate power. While NASA directed the Saturn V program, the stages of the rocket were contracted out to private corporations Boeing, North American Aviation, and McDonnell Douglas.

THE OUTCOMES OF THE TECHNOLOGICAL INVESTIGATIVE ANALYSIS

Using the SST framework in an input/output model, it was shown that Soviet and American sociopolitical values strongly influence distinct technological design elements of air and spacecraft. In the West, American capitalist values influenced the F/A-18 and the Saturn V to be complex, multipurpose, technically accurate and precise, expensive, and modern. American aerospace technology was also very collaborative, implementing instruments from many different influences as a result of the American commercial aerospace industry being so powerful. In the East, Soviet socialism influenced technology to be simpler, more inexpensive, generic and standard, technically outdated, and highly militaristic leading to occasional overcomplication. Soviet technology was also influenced by collectivism, using no experimental or new ideas that might be power grabs for individualistic engineers.

The investigative work done in this STS thesis informed on how social and political ideologies influence technological innovation. Continuing this STS analysis of the relationship between societies and technology, future investigative work into this topic should broaden the scope of inputs and technologies. Two factors that remain constant in the world are change and conflict. Because of this, new sociopolitical values are always appearing alongside innovation in aerospace technology. Understanding the societal influence of technological innovation using an input/output model of SST supports the idea that technological progression of the world is fueled by social structures. Therefore, in order to deepen the understanding of sociotechnical dynamics in a constantly changing world, the new sociopolitical values must be analyzed. Additionally, the technical research investigates this relationship between societies and future technology and the STS thesis considers this relationship with past technology. Expanding the scope of future work into this topic to include current technology would further deepen the understanding of human progression by covering the past, present, and future of technological innovation. This investigative and comparative analysis confirmed the validity of using an input/output interpretation of SST to understand the dynamic relationship between societies and technology. Therefore, this STS thesis allows future researchers to implement this model for future studies, better understanding societies as a driving force in technological design.

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