Co-Navigational Aquaculture Vehicle System Design
(Technical Project)

Bureaucracy in Defense and the Emergence of Digital Engineering in a New Era
(STS Project)

A Thesis Prospectus
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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

The United States defense industry is oftentimes closely associated with spectacular and envied "science fiction" technology that has been developed over the last seven decades. Military enthusiasts around the globe have marveled over the thousands of systems built to protect democracy within the United States' borders. Stealth aircraft technology like Lockheed Martin's F-22 Raptor; surveillance and reconnaissance systems like the U-2; precision arms and advanced electronic warfare systems; hypersonic systems, GPS, and airborne laser communication; these are all some of the most influential technologies that have been implemented in America's defense (The Skunk Works® Legacy, 2020). By the 1970's, America was perceived internationally as an unstoppable force, and was foreseen to continue to outpace its rivals and allies for decades (Servan-Schiber, 1968). Yet, America's highest-ranking officers and senior defense leaders have voiced apprehension provoked by increasing military capabilities of international adversaries. It has become clear that the Research and Development (R&D) landscape has changed globally, United States is unable to keep up as it once did, with China and other aggressors developing capable defense sectors (Berenson, 2021; Arraf, 2021). One culprit for the "diminished competitive edge" of America's defense technology has become more transparent as threats have risen: bureaucracy and the status quo. Although the phenomenon of bureaucracy has existed throughout time in defense industries, its effects has become remarkably worse since the 1950s and 1960s. R&D spending has remained stagnant in aerospace and defense industry, while industries like software and internet, computing and electronics, and automotive have risen from ranges of 90-800 percent in the last two decades (Goehle, 2018). Current defense companies have captured some of the world's brightest engineers and thinkers –

but the industry is plagued with sluggishness, repeated poor practices, and has created a supremely low incentive for innovation of next-generation advanced weapons systems.

Fortunately, with the rapid and immense development of newer technologies within our commercial sector – particularly software in Silicon Valley – America's defense industry has taken small steps to invest in better technologies for tomorrow, which could counter the traditional bureaucratic system: more specifically speaking, through autonomy. Conglomerates like Apple, Tesla, Amazon, Waymo, and Microsoft, have led the charge in artificial intelligence (AI), machine learning (ML) and autonomous technology development. Through the help of private investments and tech-savvy engineers from the commercial sector, startups and small corporations have embarked on non-traditional ways to innovate for the nation's defense using autonomy in their products. And more than ever, unmatched Silicon Valley software engineering talent has – for the first time – started to migrate towards defense with the introduction of autonomous vehicle technology. Most recognizably, these companies include Shield AI, AeroVironment, and Anduril Industries (Insinna, 2021). The introduction of designing unprecedented autonomous technology has led to a new realm of defense contracting that could be far more efficient and effective than the current approach to innovation and R&D. The rise in such systems could have huge ramifications for the future of defense contracting and developing advance military technologies within the next decade.

In attempt to connect the technical facets of the STS aspect of my thesis, I will be pursuing a technical research topic through my Mechanical Engineering Design Capstone. This technical research will explore how autonomy is utilized for civilian/commercial applications rather than military purposes – more specifically, this application lies in the aquaculture industry, and how the implementation of a new autonomous technology will improve the current operation of the aquaculture. With an increasing demand for more reliable and sustainable food sources, aquaculture has become a pivotal surrogate for the agriculture industry; offshore fish farming is predicted to "increase by a further 15% by 2030," (Towards Blue Transformation, 2022). Firstly, it is clear that marine aquaculture operation results in a reduced carbon footprint and requires fewer resources from both land and in fresh water (NOAA, 2020). Fish farming provides humans a feasible and sustainable source of protein, as carbon emissions required to maintain aquaculture are multiple factors lower than that of other land organisms such as cattle/beef (Petsko, 2021). Secondly, offshore aquaculture provides exceptional convenience with minimal disruption of coastal activity. Farms are located hundreds of miles offshore, alleviating concerns regarding hazardous coastal transportation and congestion (Morro, 2022). In order to adapt to this new style of sustainable farming, however, there are outstanding steps that remain unsolved. These problems include economical farming, safety risks for workers performing maintenance, and transportation to and from shorelines. The rise in autonomy and AI provides the perfect opportunity to eliminate such problems altogether. The development of an energy-independent autonomous system – an autonomous underwater vehicle (AUV) and autonomous surface vehicle (ASV) – with maintenance/operational capabilities will be a key artifact in refining current procedures.

Technical Topic

The current system used by offshore aquaculture facilities requires transportation of drivers hundreds of miles off the coast – utilizing ample gas and polluting the ocean. Once there, the job of fish pen cleaning and maintenance requires high risk safety issues – diving to clean the fish pens is not an easy nor safe task as it requires large depths and unruly fish handling. As an existing system we hope to improve, we will be adding capabilities to a remotely operated vehicle (ROV) to become autonomous and compatible with a surface vehicle developed to harvest wave energy and provide a sustainable source of energy to both vehicles. The BlueROV2 is the ideal ROV to begin with due to its open software design and ability to easily take on modifications (BlueROV2 Buyer's Guide by Options, 2022). Development of these devices will reduce exposure to danger, while also making the processes less-time consuming and costly overtime, especially as popularity of aquaculture increases with growing food demand.

In order to automate the devices, ROS, or Robot Operating System, will be used alongside pre-selected sensors to not only properly move along and clean the fish pens, but to also provide tracking information to those using the technology on the farm. Furthermore, the surface vehicle (ASV) and underwater vehicle (AROV) will be connected via a tether to permit the transmission of wave-harvested energy from the ASV to the AROV. The project will be completed by our team of five over the course of the Fall and Spring semesters of the 2022-2023 school year in the ME Design courses, with our client being our professor, Tomonari Furukawa and teaching assistant, Julia Rudy. It will then be further curated by future capstone groups and eventually handed off to the Department of Agriculture.

Further work surrounding these aquaculture projects is being done by Stevens Institute of Technology, MIT, Cornell University, and Virginia Tech. Our project is most closely aligned with Stevens and Virginia Tech, where there are different autonomous devices being designed for various aquacultural jobs. Though these other projects serve as a guide in our work, most of the focuses of our work were developed through the design process, as shown in Figure 1.

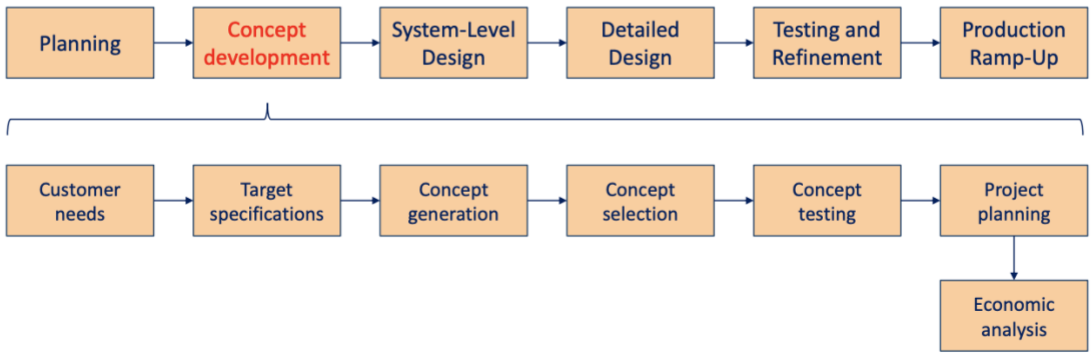

Figure 1 (Furukawa, 2022)

Through interviews and assessment of customer needs, the target specifications and goals of our project were developed, which then drove forward the concepts we have generated and selected for testing.

Thus far, our goals have been to take our target specifications and find the proper corresponding hardware and develop the proper software to develop a mostly working device by the end of the fall semester. By the Spring, we hope to have a device with all kinks hashed out, and that can be presented to different laboratory groups.

STS Topic

In order to understand the current elements of bureaucracy and adherence to the status quo within defense, extensive historical background information is extremely relevant. When effectively diagnosing a problem, especially one that has persisted and worsened, understanding the roots of the dilemma is imperative. I hope to explore this information in great detail in my thesis, as it will provide clarity for why and how current processes can be changed.

The Department of Defense (DoD) has had some of the most powerful weaponry and technology that was built to directly deter and prevent a war to breakout – but this is no longer the case. The ten largest defense conglomerates, which account for over 86% of the revenue in the industry today, have been able to build some of the most sophisticated and effective hardware systems for warfare in the 20th century (Courage to Learn: Defense & Aerospace, 2022). Rather, America's software development for AI and autonomy in defense is lacking. The future of the battlefield will rely on "artificially intelligent, unmanned systems, which fight, gather reconnaissance data, and communicate at breathtaking speeds" (Stephens, 2022, p. 34). "Ubiquitous" and "affordable" systems like unmanned air/ground vehicles will have the upper hand on the battlefield through acquisition of data, immediate passing of information, and machine decision-making to "strike the enemy from safety" (Future of Defense Task Force Releases Final Report, p. 01; 2020). With this, sweeping changes could very well occur in current processes of innovation; these include changes in the political landscape of the defense industry, social and demographic shifts in Silicon Valley engineering talent, challenge to the political bureaucratic process, and the exposing of the industry's breakdown as an infrastructure (Star, 1999).

The primary STS framework I intend on using for this piece is Langdon Winner's "Do Artifacts have Politics?". This framework explains how artifacts are inherently political in that they require or are strongly compatible with a particular kind of political arrangement (Winner, 1980). It is inarguable that the products developed among current defense contractors are without political intentions – interaction between firms being awarded contracts from the DoD and how systems created from those firms create politics, either supporting or opposing a form of status quo. Such politics could include the motives of the company in encouraging the existing bureaucratic system, or they could provide a counter-argument against traditional processes of innovation in the defense sector.

The primary challenge I face in writing my STS thesis is finding a source that can provide evidence that directly correlates how implementing autonomy and AI affects the bureaucratic system and status quo of current defense contractors. There is an overwhelming abundance of literature supporting the existence and worsening of government bureaucracy in the industry, and also sources pointing to the increasing use of drones and robots in warfare; yet, there are few that truly correlate the two ideas together, and I am eager to find ways in which they will intersect with one another using my research and analysis. Furthermore, the complexity of such a system is overwhelming: the mechanics of current contracting, politics involved with funding, and current special projects unknown to the public pose difficult questions that require extensive analysis. Lastly, given that this change is currently taking place within a highly-populated and chaotic democracy like the United States, there are always elements of uncertainty, and it is both impossible to exactly predict the direction of innovation in this country.

I anticipate that from this research, I will be able to more comprehensively understand if autonomous technology will enable the United States to reboot its arsenal and become competitive with its adversaries as it once was – and more importantly, expose the ways in which the current status quo needs to be changed and begin to encourage innovation.

Research Question and Methods

So, in discussing this as an STS topic, what changes does autonomy through AI technology bring to America's defense innovation, and how might that counter the current bureaucracy problems within the defense industry?

In order to retrieve data and accurate information to address this question, my plan employs three different research techniques. First and foremost, I will find literature published by government agencies involved with policymaking, intervention, spending, and interacting with the Department of Defense and large defense contractors. Some of this literature could exist in both libraries as well as government databases, and it would provide information necessary for historical context, current budgets and funding, and quantitative analysis.

Secondly, I plan on researching commercial based companies including startups, growth companies, oversees corporations, and large software-based conglomerates pursuing AI and ML technologies – this includes analyzing funding trends from private investors like venture capitalists, gathering data in showing shifts in engineering talent, and reading about oversees competitors. I also intend to gather more online qualitative sources from research publications discussing the societal and social ramifications of autonomous vehicle technology in commercial but also civilian applications (Rao, 2016).

Lastly, my own experiences have shaped my perspective on government bureaucracy in defense – from working for three months at a leading unmanned aircraft manufacturer in Southern California, I witnessed firsthand the effects of sluggishness, overbearing government specifications, and even shared frustration among engineers. Therefore, I hope to pursue interview methods that will provide valuable anecdotal information from engineers and other internal employees at my previous employer/other defense contractors. I will also be in contact with individuals previously employed at the company of my summer internship who are now employed at other aerospace and defense manufacturers. Some of these companies include Shield AI, Tesla, Anduril, AeroVironment, and Insitu. These interview methods will be crafted thoroughly and carefully in order to control variables such as age, time working in the industry, private or public companies, engineering discipline (if any), and company products.

Conclusion

If executed properly, a fully-autonomous system incorporating and upgraded BlueROV2 Robot will be produced, presented to several different research teams for critique, and further developed through extensive design iteration by the end of the Spring semester. It will bear guidance, navigation and control (GNC) and GPS systems that allow the offshore farms to track progress of cleaning and maintenance activity, as well as tethering and connectivity to a surface vehicle that performs self-docking and wave energy harvesting for both devices. The improved system will effectively produce safer and more sustainable aquaculture farming practice.

As the STS topic addresses, through thorough data collection with 3+ methods of research, I hope to discover whether the typical bureaucratic roadblocks to innovation in the defense sector will change in the face of new AI tech and new industry structures and strategies. Depending on my findings, this research could be useful for policymakers when allocating funding towards particular contracts and projects, engineers, project managers, and other employees who are stuck in the unpleasant and slow R&D cycle at large defense conglomerates, and even private investors who are typically closed-minded to investing in developed industries – like defense. I am fascinated to see how the industry will change in the next decade with the introduction of this new technology, and I am hopeful that my research will shine a light onto how the the broken system of innovation can be renovated in this country.

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