Engineering Education and its Connection to the Defense 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

Many universities across the country have made national headlines after their student body protested the appearance of Raytheon, Lockheed Martin and other defense contractors at their career fair. Many examples of protest in spring 2023 appear to be concentrated in New England at universities such as UMass Amherst, Northeastern, and Tufts (Bohl, 2023; Mailly, 2023; Reardon, 2022). These student protests highlight the defense industry's dominance in career opportunities for many engineering students, particularly those in Aerospace or Mechanical Engineering programs.

The defense industry's prominence in engineering career opportunities is part of a larger sociotechnical phenomenon of the intertwinement between engineering education in America and the defense industry. Although engineering education programs that are influenced by the defense industry will prepare students for the technical work in any future career, these programs might not provide their students with the ethical and moral education to evaluate the morality of future work.

To study this phenomenon, I will be posing the research question, why is working in the defense industry one of the most prominent career paths for Mechanical Engineering students? By studying this research question through engineering education literature and defense policy analysis, I believe that I will reveal a deep intertwinement between engineering education and the defense industry. I also believe my research will reveal that this intertwinement between the education systems and defense industry is no accident. Key actors including university leaders, students, defense corporations and the federal government have all contributed to this phenomenon.

The research of the connection between engineering education and defense industry begs a follow-up question, is the intertwined education affecting the engagement of engineers? An engaged engineer is an engineer who is ethical, socially conscious, cares about public welfare and understands the consequences of technology (Cech, 2014). Defense initiatives could be the reason why an engaged Science, Technology and Society, STS, education is not prioritized by many engineering programs. Many of these engineering programs across the country prepare their students for technical work in any future career, but they might not provide their students with the ethical and moral education to evaluate the morality of future work. The limited STS education of many engineers could be instrumentalized by the defense industry to enforce the status quo. I believe my research will reveal that an engineer's STS education must be an engaged and critical one. I hope the study of engineering education's intertwinement with the defense industry might reveal some shortcomings of this education and areas of future improvement.

Background and Significance

The military industrial complex was created during WWII to respond to the issues America was facing during a modern global war. Politicians of that era believed that the military industrial complex needed to stay after WWII because the improvisation of national defense, as was typical for America before WWII, would be too risky (Eisenhower, 1961). During the Cold War American politicians were concerned with developing superior technology over our adversaries and to stay ahead of the threats. The defense industry's effects on American society were noticed by laymen and politicians during the Cold War. With the rise in prominence for the new military industrial complex, Eisenhower warned the nation to guard against "unwarranted influence" by the military industrial complex in his farewell address (Eisenhower, 1961).

Eisenhower also warned the nation that university research had the potential to be dominated by "Federal employment, Federal project allocations and the power of money" (Eisenhower, 1961). At the time of his farewell address the United States was spending more on military security than the net income of all United States corporations (Eisenhower, 1961).

During the end of the Vietnam War in 1973 the defense spending as a percent of our gross domestic product had dropped since Eisenhower's farewell address but academics were starting to argue that the military spending needed restraint (*Defense Spending as a % of Gross Domestic Product (GDP)*, n.d.). In Leitenberg's *the Dynamics of Military Technology Today*, he argues that we should be asking if certain military technology is a necessary investment. Many involved in the military industrial complex thought extensive spending on research today was necessary to build the technology of tomorrow and stay ahead of our enemies (Leitenberg, 1973). Leitenberg was concerned that the military funded 65% of engineering research in the 60s and funded many graduate degrees. Compared to civilian manufacturing at this time, military research costs were 10x higher per unit output (Leitenberg, 1973). The opportunity cost of the expensive military research of the past and present is unknown. Sometimes dual-use technologies, things like GPS technology that help civilians, are used to justify the expense of military research. Leitenberg argues that a marginally beneficial byproduct is a poor way to justify military research when military research gets higher priority and more public funding than other kinds of research (Leitenberg, 1973).

Today it seems Eisenhower's and Leitenberg's worst nightmares regarding the military industrial complex have come true. Although defense spending as a percentage of GDP has trended down since the 60s and 70s, the defense industry has maintained significant influence over university research (*Defense Spending as a % of Gross Domestic Product (GDP)*, n.d.).

From the late 80s to the late 2000s, defense has accounted for almost 60% of all public research and development spending (Moretti et al., 2019). Today the Department of Defense, DOD, alone is the third largest public source of University funding (Olivier, 2022).

Private corporations in the defense industry have also exerted extreme influence over American universities. Lockheed Martin, a prominent American defense corporation, has almost 60 partner universities across the country (Olivier, 2022). Many of these universities receive research grants from Lockheed, have an endowed professorship, and some have a "Lockheed Martin" day. At these Lockheed Martin days, the company brings military technology and vehicles to campuses to help recruiting. In addition to official university connections, Lockheed Martin also awards many scholarships, well-paid internships, and student loan repayment programs to help students with the financial burden of university education. Although a major player, Lockheed Martin is just a single corporation in the defense industry. When looking at the total impact of the entire industry, the effects are pervasive. Some engineering programs, schools, and even entire universities would not survive without the funding from corporate sponsored defense research. (Olivier, 2022)

Given the historical and modern effects of the defense industry on engineering education, I will be asking, why is working in the defense industry one of the most prominent career paths for Mechanical Engineering students? As a follow-up, I will also be asking, is defense-intertwined education affecting the engagement of engineers? I believe my research will show that the defense industry has a strong influence on engineering education in America. Engineering education strongly influences the career paths of engineers and an education intertwined with the defense industry could explain why defense industry careers are so popular among Mechanical Engineering graduates. Additionally, I believe my research will show that the intertwined engineering education might not adequately provide the humanities education for engineering students to ethically evaluate their future technical work.

This phenomenon is important to everyone in society because I believe it can reveal some of our priorities for engineers. The industries that receive the most engineers are the fields where the most scientific design and progress will take place. Additionally, the lack of engineers in other industries due to the defense industry's prominence affects the type of technologies that don't get developed. A defense budget directed towards engineering education could create a self-fulfilling prophecy on what type of technology gets developed. Therefore, the industry with the most engineers and the industry that affects engineering education the most might reflect some of society's priorities for engineers.

On a more personal level, the intertwinement of engineering education and the defense industry has been present throughout my entire life. It is now abundantly clear to me that many of my STEM educational experiences were influenced by the defense industry. I was absolutely influenced by the system put in place and one might even say I was in the defense workforce pipeline. This influence culminated with the DOD funded SMART scholarship. This scholarship covered all expenses for my education in the last two years of school in exchange for two years of civilian service as an engineer in the DOD. I am grateful for all the educational opportunities afforded to me by the defense industry initiatives and I know I would not be where I am today without them. However, the goal of this paper is to examine what is happening with the social structures intertwining engineering education and the defense industry, and how this intertwinement affects the education of students like me.

Methodology

In this paper I will be studying the complex social structures behind the relationship between engineering education and the defense industry. Some of the actors I will look at involved in these relationships are university leaders, students, defense corporations and the federal government. There are many different power dynamics between these actors that I will try to understand. The defense industry exerts power over engineering education through funding, grants, and employment. Engineering education exerts power over industry by researching the technology that will help the companies stay ahead of competition or that helps the government reach its goals. The government exerts power over industry and universities by choosing who gets the most funding and shaping policy that affects both actors.

My methods of research will include primary source policy analysis and secondary source academic literature review. My policy analysis will focus on the defense industry or DOD initiatives to prepare or educate a defense industry workforce. I will be looking for the specific methods of influence mentioned in these initiatives and who is being targeted with them. More broadly, I will also look at government policy affecting all higher education and how this policy might reinforce the defense industry initiatives. Other primary sources I will use in my research are the Accreditation Board for Engineering and Technology, ABET, engineering curriculum requirements, student accounts on their defense related capstone projects, and professor reflections on how their defense technology courses impact students. My academic secondary sources will include writings about educational entrepreneurs who used Cold War defense money to grow their schools and writings about the intertwinement of a military-industrial-academic complex. My secondary sources will also include topics about the current and historical state of engineering education. I will review writings about critical thinking in an engineer's work and the culture of disengagement in engineering education.

It is important to note that I will incorporate some of my own experiences as a primary source where relevant in my analysis. In my research I encountered some phenomena that have echoed my experience or initiatives that I believe have directly influenced my experience. In these encounters I believe that it is valuable for me to include my own perspective while recognizing the effects that my association with this social system may have on the analysis.

Literature Review

The intertwinement between the defense industry and engineering education stretches back to World War II and continued to grow in the coming decades. In 1973 Milton Leitenberg expressed his concern about the rising defense expenditures on engineering education in his article *the Dynamics of Military Technology Today*. Before this publication, the military funded 65% of engineering research in the 60s which included the funding of many graduate degrees. Additionally, military research costs were 10x higher per unit output than civilian manufacturing research (Leitenberg, 1973). During the Cold War arms race, technological superiority was seen as a vital aspect of national defense and many in the defense industry believed that extensive research spending was necessary to stay ahead of our enemies (Leitenberg, 1973). Leitenberg argued that we should be asking on a case-by-case basis if the investment would be better spent elsewhere. In his publication, Leitenberg noted that military officers are not the only ones to blame for the extensive spending. It was civilians working for the DOD that first advocated for the multiple independently targetable reentry vehicle (MIRV) ballistic missile program (Leitenberg, 1973). This program is an important example of the wide web of actors, including civilian officials, whose actions affect the spending that supports the military-industrial-academic complex.

University officials are another group of actors who helped fuel the military-industrial-academic complex during the Cold War. In Kindel and Stevens', *what is educational entrepreneurship? Strategic action, temporality and the expansion of US higher education*, the authors examine the Stanford Engineering School's expansion under Frederick Terman. Frederick Terman aggressively pursued federal grants as a method to grow his school and founded the Honors Cooperative Program (HCP) to start the growth process (Kindel & Stevens, 2021). The post-grad students enrolled in HCP were a way for Stanford to generate close ties with local industry. After HCP helped build Stanford's reputation, the program was used to build ties with the federal government (Kindel & Stevens, 2021). After the Soviet's launched Sputnik 1 and Americans feared possible Soviet technological superiority, Terman used the social issue to lobby for more engineering funding. Terman's lobbying for engineering research as a means of defense catalyzed a whole wave of federal funding for engineering schools across the country, including Stanford. Authors Kindel and Stevens call Terman and similar university officials "educational entrepreneurs." Educational entrepreneurs recognize the university's position as a hub between families, academia, government and private corporations. Educational entrepreneurs then use this position to devise academic solutions, like research, to solve societal problems, such as national defense fears (Kindel & Stevens, 2021). The actions of educational entrepreneurs led to the historic growth of higher education in America and laid the groundwork for the current engineering education environment. Educational entrepreneurs like Terman are some of the many actors responsible for intertwining engineering education and the defense industry by increasing military funded engineering research.

Engineers working in the military are heavily involved in socio-technical systems that need to be considered in the development of military products. In *Technology, Organization and Power* by Rene Moelker, the author examines different ways social systems have interacted with military technology. Sometimes, societies completely reject military technology as it will disrupt traditional power dynamics. As evidence, Moelker points to ancient Israel where Jewish forces were known to destroy all captured chariots and horses, rejecting a new military technology. The Israelites knew an army primarily consisting of primarily horses and chariots would be expensive and required a centralized monarchy which would disrupt the traditional power balance between the federation of tribes (Moelker, 2006). In other cases, social systems are slow to accept new technology which slows its development. In colonial France, traditional noble led branches of the army were slow to adopt the use of artillery. Lieutenant-General De Gribeauval was able to convince the traditionalists to use artillery after experimentations, field demonstrations and finally successful use in battle (Moelker, 2006). Finally, social groups can completely change the development and effectiveness of a technology while it is being used. The M-16 was an incredibly reliable gun developed by the Armalite Corp, a small defense corporation, before the Vietnam War. Threatened by the disruption to the military fireman market, the Ordnance Corps, who previously held majority market share, “improved” the M-16 so the federal government would buy it from them. The “improvements” made the gun less reliable and the worse product resulted in a higher American fatality rate (Moelker, 2006).

Moelker primarily focuses on how socio-technical systems affect the use of weapons technology and I think this point should be taken one step further. If an engineer is to fully understand the consequences of the defense products they are creating, they must understand the socio-technical systems these products are being used in. If an engineer wants to successfully reduce civilian casualties and the other horrors of war, they need to fully understand how their designs will be used.

Current engineering education does not focus on teaching engineers the tools to understand the socio-technical systems that their technology is being used in. Although many programs include some kind of ethics or science, technology and society course, these classes are normally an afterthought in curriculum development. The authors of *Critical Thinking and Judgment on Engineer's Work* argue that engineering education should include more humanities classes in a way that cohesively integrates these humanities classes into the framework of the engineering educational experience. The authors argue that ABET's definition of engineering includes complex concepts like "judgment," "economic use of resources," and "benefit of mankind" while ABET does not promote an education that interacts with these ideas (Giuliano et al., 2022). Engineers will not be able to conclude that they are helping humanity if they do not look at their judgments from a holistic perspective. The authors argue that engineers with good judgment must put ethical and critical thinking, developed from the humanities, into practice with the technical. The authors also argue that, if there is no ethical thinking, rational systems can be imposed on an engineer and reduce their effectiveness to an uncritical agent (Giuliano et al., 2022). I believe engineers without ethical thinking skills can still be incredibly effective from a technical standpoint. Regarding helping humanity, I agree that an uncritical engineer is less effective than a critical one as an uncritical engineer can be instrumentalized to accomplish the goals of an immoral institution.

Discussion and Results

The federal government has been passing legislation that directly connects engineering education and defense initiatives since the Cold War. After the USSR launched Sputnik, Americans were afraid that American technology was falling behind the Soviet's. Congressmen seized this opportunity to pass legislation to help strengthen STEM education to alleviate national defense fears (*U.S. Senate: Sputnik Spurs Passage of the National Defense Education Act*, n.d.). This legislation was the National Defense Education Act of 1958. The goal of this first direct link between engineering education and defense was to ensure that American had enough trained manpower to meet its national defense needs (National Defense Education Act, 1958). To reach their goals, the federal government pledged to give $280 million, over the course of 4 years, to the states for STEM educational improvements for school children ages 5 to 17 (National Defense Education Act, 1958). Reading between the lines, this part of the act could be seen as a way to start the defense workforce pipeline at a young age. Additionally, the act funded 5500 national defense fellowships, over the course of 4 years, for graduate degrees in STEM fields (National Defense Education Act, 1958). Preference for these fellowships was given to those who wanted to teach at higher institutions and would further develop a well-educated STEM workforce that could be used for defense. The National Defense Education Act helped set the precedent of passing legislation to develop the military-industrial-academic complex as a means of national defense.

Seven years later the federal government passed the National Higher Education Act of 1965, HEA, to further develop the military-industrial-academic complex. The HEA increased funding for American Universities, increased Masters and Doctorate fellowships in the STEM fields, and provided scholarship opportunities to veteran's dependents. The act also established a national STEM database of all available federal, state, local and private STEM scholarships with the goal of making funding easier for STEM students to find (National Higher Education Act, 1965). A major part of the HEA was providing institutional aid and improvement for minority science and engineering programs. The federal government acknowledged that the underrepresentation of minorities in STEM fields diminishes our nation's technological competitiveness (National Higher Education Act, 1965). In the arms race era, technological competitiveness was a cornerstone of national defense. To remedy the underrepresentation of minorities in STEM fields, the act planned to increase funding for STEM programs at HBCUs. Additionally, the act aimed to determine what factors limited STEM professional participation and what factors encouraged study in these fields. Once the research was completed, the federal government planned on launching a marketing campaign encouraging young Americans to take up studies in STEM (National Higher Education Act, 1965). The most interesting part of the planned marketing campaign was the effort to tie the participation in STEM careers to the concept of service to one's country. Although serving one's country can take many different forms, in this context the campaign was trying to loosely link STEM careers to military service. By tapping into patriotic spirit, this campaign hoped to boost participation in STEM. Funnily enough, when I've mentioned my DOD scholarship and future job to people, I've had older people say "thank you for your service" to me as if I was a veteran.

Much defense legislation has been passed since the 60s to reinforce the connection between engineering education and the defense industry. Modern defense strategy shares many of the same themes regarding STEM education. The National Defense Strategy 2023, NDS, seeks to build enduring advantages across the defense ecosystem, which explicitly includes the DOD, the defense industrial base, private corporations, and academia (*National Defense Strategy*, 2023). To build these enduring advantages the DOD plans on working closely with universities build the future workforce, increase federally funded research, and increase the availability of fellowships (*National Defense Strategy*, 2023). Along the same lines as the HEA, the DOD wants its workforce to represent all of America so they will broaden hiring pools and look at a diversity of backgrounds as part of the NDS (*National Defense Strategy*, 2023).

The National Defense Industrial Strategy 2023, NDIS, is the strategic vision to build a modern defense industrial ecosystem. The DOD believes there is an inadequate workforce of skilled workers to meet potential defense demand. The number of manufacturing jobs and defense related STEM jobs has contracted over the last few decades (*National Defense Industrial Strategy*, 2023). The NDIS seeks to address this challenge by developing an advanced manufacturing workforce pipeline through funded apprenticeships, internships and by destigmatizing industrial careers. The DOD will increase investment in Manufacturing Innovation Institutes that train technicians, scientists and engineers (*National Defense Industrial Strategy*, 2023). Through the Manufacturing USA Network the DOD will collaborate with universities, high schools and even youth groups like the Girl Scouts (*National Defense Industrial Strategy*, 2023). The NDIS plans to invest in DOD Education and Research Programs in HBCUs and MIs (Minority Serving Institutions) to expand recruitment in non-traditional communities. Private corporations are also following NDIS initiatives to recruit from non-traditional communities. About 60% of Lockheed Martin scholarships are awarded to minorities to build a diverse employee pipeline (Olivier, 2022). The National Defense Science and Technology Strategy 2023, NDST, touches on many of the same points as the NDIS. In addition to broad STEM workforce investment, the NDST wants to target young Americans. The DOD wants to build STEM skills through competition to get young students excited about pursuing a career in STEM (*National Defense Science and Technology Strategy*, 2023).

The effects of past and present defense legislation can be seen in many tangible examples in engineering education. All ABET, the Accreditation Board for Engineering and Technology, accredited engineering schools must require their students to take a capstone design course where they apply the theory they've learned in the classroom and bring it to the real world. Some engineering capstones are funded by or work directly with the DOD. *Leveraging DoD Relationships and Interests to Improve Undergraduate Education and Enhance the Structural Engineering Profession* describes how civil engineering students at West Point worked with the Naval Facilities Engineering Command to test explosive resistant concrete (Bunn et al., 2021). In their paper, the authors describe how working with the DOD is mutually beneficial for students and the DOD (Bunn et al., 2021). Military academies are not the only type of schools with DOD funded capstones. Here at UVA, a public university with renowned humanities departments, my capstone advisor offered us the opportunity to work on a project developing ultra-light strain gauges that could be attached to the internal components of a missile and gather data during a test flight.

Some universities also offer courses, beyond capstone design classes, that directly link engineering education to the defense industry. At UNC, professors have developed a mechanical engineering course that teaches students about the military significance of topics previously covered in other mechanical engineering classes (Dahlberg et al., 2020). This class was designed to be veteran friendly and help connect student veterans to other classmates. Quantitative data gathered by the course developers has shown that students are more interested in pursuing STEM careers in the military or DOD after taking this class (Dahlberg et al., 2020). Universities, in addition to defense policy, play a critical role influencing students to join the military technology workforce.

I believe my experiences in primary and secondary school help show the effectiveness of developing a STEM workforce pipeline outside of the classroom. At every age, my STEM educational experience was the poster child of DOD initiatives. In elementary school in participated in STEM competitions through cub scouts and the Math Olympiad program, which was funded by Raytheon. These programs sparked my interest in STEM studies. In middle school, I participated in engineering summer camps and went to STEM conventions during the school year. In high school the tie between STEM education and the DOD became more obvious as I joined Civil Air Patrol, part of the Air Force Auxiliary, to learn more about aerospace engineering. Finally, half of my college engineering education was funded directly by the DOD through the SMART Scholarship, which requires me to work for the DOD after school. When my STEM education is put in context of the DOD legislation, my experience is a perfect example of the defense workforce pipeline working as the DOD intended.

The intertwinement between engineering education and the defense industry is clearly documented above and by other scholars. However, the intertwinement's effect on engineering education is not as well documented. In Erin Cech's *Culture of Disengagement in Engineering Education*, the author discovers a concerning trend of disengagement in all different types of engineering programs across the country. Cech measures engagement by studying concerns for public welfare measured through the students' perceived importance of professional responsibilities, the consequences of technology and how people use machines. Cech's data shows a decrease in all categories of public welfare concern after college engineering education (Cech, 2014). Cech's data includes students from all backgrounds at an elite technical private school, MIT; a large public land-grant university, UMass Amherst; an engineering only college, Franklin Olin College Engineering; and a women-only liberal arts college, Smith College (Cech, 2014). Cech attributes the decrease in public welfare to an institutional emphasis on the technical education being seen as more important than the social or humanities education in engineering programs.

The emphasis on technical education being more important than humanities education can be seen in the requirements for ABET accreditation. ABET sets clear, high expectations for introductory college math/science and department specific engineering coursework by respectively requiring 30 and 45 credit hours of classes or labs (ABET Board of Delegates, 2023). In contrast, ABET sets no clear requirement for humanities or moral education as they only ask for “a broad education component” to tie into the rest of the curriculum (ABET Board of Delegates, 2023). To satisfy this requirement, many engineering programs only require their students to take one ethics or humanities class. Even at UVA with our extensive science, technology and society curriculum that requires students to take 12 hours of these classes, many students and professors still think of the non-technical classes as an afterthought.

I believe that humanities education as an afterthought in engineering education might be a direct result of the defense industry’s monetary influence over engineering. The DOD has a strong, documented interest in developing a technically proficient STEM workforce to accomplish national defense goals. To promote this interest, the DOD has heavily invested in engineering education for decades. This level of investment has established the defense industry as a major source of funding for public engineering research, allowing the defense industry to influence engineering education. However, the defense industry has shown no emphasis on developing the STEM workforce’s humanities education or public welfare engagement skills. Although the lack of humanities education for engineers might be unintentional, this system still creates uncritical and disengaged engineers. A disengaged engineer is less likely to evaluate the morality of each project they work on and more likely to only focus on the technical.

Conclusion

The impact of the defense industry on engineering education is undeniable. The federal government has led a concerted effort to promote a STEM workforce pipeline through engineering education. University officials, private corporations and students have all contributed to this intertwinement between engineering education and national defense priorities. This intertwinement and the monetary interest of the defense industry in engineering education helps explain why many of the engineering jobs are in that industry.

Developing technology for the military is important work where the consequences involve human lives. The consequences of military technology are deeply affected by the social systems in which the technology is used. Engineers in this industry need to be aware of the communities involved and develop the critical thinking skills necessary to evaluate the morality of their work. The current engineering curriculum does not focus on a humanities education necessary to develop critical thinking skills and promote public welfare concern. The culture of disengagement present at all engineering schools shows a flaw in modern engineering education. A change in national engineering curriculum requirements, national curriculum framework and engineering education priorities might be necessary if we want to see more engaged engineers. A new engineering educational framework incorporating the humanities must teach engineers to be critical or else this education could still be instrumentalized by the defense industry to accomplish all their goals, moral or not.

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