Bureaucracy in Defense and the Emergence of
Digital Engineering in New Era

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Charles Tilney-Volk

Spring 2023

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

Advisor

Michelle (MC) Forelle, Department of Engineering and Society

Introduction

Palmer Luckey was no ordinary teenager—dropping out after only two years of college, Luckey was a self-taught engineer who was transfixed on technology journalism. At the age of 16, his obsession with virtual reality had escalated into him transforming his parents' basement into a jungle of gaming devices and electronics hardware. Tinkering with anything he could possibly get his hands on, he soon began developing functional prototypes of his virtual reality ideas and concepts. After years of development, Luckey began to post his designs on a plethora of internet forums, sharing his ideas with hundreds of electrical, software, and computer engineers.

John Carmack – the creator of the iconic *Doom and Quake* video game franchises – quickly noticed Luckey's ideas and potential. And to Luckey's surprise, the public response was overwhelming. People were mesmerized by his invention, and his following skyrocketed. With the help of Carmack and other engineers, his invention soon turned into a product—the Oculus Rift VR headset. He raised upwards of $2.5M in a matter of weeks, and by 2013, his team had received over $91M in venture capital funding (Ewalt, 2015). This Oculus design hit the market running and was an instant success. Oculus VR was sold to Facebook for $2B in cash and stock, making him among only a handful of individuals in world to become a billionaire before the age of 30 (Stone, 2017).

However, it's not every day that someone goes from creating a virtual reality headset to founding a cutting-edge defense technology. Harnessing his entrepreneurial spirit and overwhelming success in high-tech and consumer electronics, he created Anduril Industries in 2017 with the help of fellow engineers from Oculus. This new company was founded on the premise of developing defense technologies in an unconventional manner – in which government bureaucracy, sluggishness, and poor practices would be eradicated using a revolutionary business model. Anduril set a new precedent for taking an entrepreneurial approach to defense contracting. It was unprecedented for a Silicon Valley-esque (SV) unicorn executives to attempt to transform and create a new business model in looming defense industry. Now, with dozens of similar defense startups following, one crucial question remains: what circumstances have necessitated a rethinking of the defense industry's approach to innovation?

Innovation and product development in the defense industry has experienced various periods of growth and stagnation throughout its history, and the factors that contribute to these shifts can certainly be complex and varied. One commonly cited period of stagnation and bureaucracy in the defense industry occurred during the 1970s and 1980s (Stephens, 2022). During this time, the defense industry was heavily focused on developing and producing large, complex systems such as fighter jets and missile defense systems. These projects often underwent years or even decades worth of R&D and project management, and the costs associated with their production were astronomical – oftentimes exceeding billions of dollars (CIA, 2011). Government regulations and bureaucracy had also become more complex and stringent, making it difficult for companies to innovate quickly or efficiently. This overbearing involvement resulted in a culture of risk aversion and a focus on incremental improvements to existing systems, rather than developing truly innovative new technologies.

Such decade-long events have accumulated and reinforced poor defense practices and dynamics; although the United States is allocating more funds towards defense contracting than ever before, the military technology has not kept up with the advancements demonstrated in other comparable industries. There is "more AI in a Tesla than in any U.S. military vehicle; better computer vision in your Snapchat app than in any system the Department of Defense owns; and, until 2019, the United States' nuclear arsenal operated off floppy disks" (Stephens, 2022). And comparably, other tech industries like software and internet, computing and electronics, and automotive have risen from ranges of 90–800% in the last two decades (Goehle, 2018). From Artificial Intelligence (AL) and Machine Learning (ML), additive manufacturing capabilities, and the internet of things (IoT) – it is imperative for the United States to continue adapting to new breakthroughs in technology to innovate and deter war effectively. Through an exploration of key recent developments, this paper will demonstrate the far-reaching implications – from business models to product design – of the introduction of these technologies in defense.

AI and machine learning are overhauling the defense industry's use of digital technology and privatized funding models because of agile and rapid software development.

Literature Review

For decades, the United States defense industry was renowned for its impressive and futuristic technology. 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 internationally perceived as an unstoppable force, and was foreseen to continue to outpace its rivals and allies for decades (Servan-Schiber, 1968).

Now, however, most traditional defense conglomerates struggle to release effective products for the battlefield. This dilemma has been compounded by problems including bureaucracy, corporate stagnation, and poor R&D practices. First, because of Department of

Defense (DoD) reforms decades ago, new and advanced technology cannot be purchased without clearly pre-defined system requirements. For corporations, pursuing independent research and development (IRAD) therefore generates little to no business value. For perspective, lean high-tech corporations currently invest approximately 15-25% of incoming cash flows on independent R&D, while defense conglomerates now spend less than 5% on pure IRAD (Maucione, 2015). Defense firms have a greater incentive to either continue production of current systems (which quickly became outdated), or stall until the government demanded a particular R&D project.

Second, these reforms were enacted as cost-control measures for a very specific era of defense contracting. Robert S. McNamara – a businessman with “a sterling reputation for administrative efficiency at Ford Motor Company” – became the new secretary of defense in the 1960s (Stephens, 2022). His new policies instituted a set of new rules for defense tech acquisition; he was confident that the United States was ahead of the Soviet Union in terms of military innovation, and thus, he prioritized primarily cost-control measures in his reforms. Adhering to this new system meant that prior to purchasing any military technologies, the government would undertake a lengthy (often years-long) process of arguing over system requirements, determining how to distribute funding and resources, and choosing which firm would be “awarded” the contract—as opposed to awarding contracts somewhat liberally (Berenson, 2021). This was a successful model during the 1960s. Now, however, obtaining new technology has become an arduous process. Defense firms are left with little incentive to develop their products quickly. This bureaucratic process not only hinders product development but promotes stagnation and sluggishness.

Lastly, the most well-established defense conglomerates in our country (Lockheed Martin, Boeing, Raytheon, etc.) employ hundreds of thousands of engineers who do not bear the same business structures and software expertise in comparison to agile SV/high-tech firms. The future of the battlefield will rely on artificially intelligent, unmanned systems, which "persistently gather real-time information, communicate at breathtaking speeds, and enhance rapid decision making" (Whitney, 2021). Such technology is enabled through advanced software and AI, and the largest conglomerates still primarily invest and develop advanced *hardware* systems. Although this hardware-rich approach created products that protected the United States for decades, they "are no longer the future of our defense" (Stephens, 2022, p. 2). Simulations and wargame models conducted by the DoD have indicated that China and other adversaries can repeatedly leverage advanced software capabilities that have a strategic edge over the United States (Brose, 2020). The ominous threat of an invasion in Taiwan for semiconductor manufacturing control and the devastating eastern European conflicts call for the American defense industry to rise to the occasion and change its trajectory of poor practices, bureaucracy, and lackluster technology.

Actor Network Theory (ANT) is a well-established framework for analyzing the unbounded interactions between human and non-human actors in the context of society and technology (Cressman, 2009). I will employ this framework to (1) identify the actors that are relevant; (2) investigate how these AI technologies are influencing behaviors and decision-making processes of human actors; (3) and identify nodes and connections within the network of actors involved in the overhauling of this industry. ANT fits well into the questions and implications of AI in defense particularly due to its simplified nature and ability to reduce complex networks in comprehensible concepts. This is known as "black-boxing" in which the underlying complexity of the system can be hidden. "Punctualization" also alludes to similar simplifications in which human and non-human actors can be reduced to a singular point or event – oftentimes, this point is presented as the central focal point around which the network is constructed. These terms and concepts will be especially useful for understanding the development of social phenomena and the emergence of AI technology in defense.

Methods

To research and argue the transformative impact of AI and machine learning in defense, I have pursued a comprehensive approach of methods for conducting research. My first step involves a highly quantitative approach: I have researched commercial based corporations including startups, growth companies, oversees firms, and larger software-oriented firms involved in AI and machine learning technologies. This analysis will include company headcount and demographic information to illustrate shifts in engineering talent; sources of funding from respective Angel groups, VC firms, and Private Equity firms; dollar amount cash flows for these defense businesses and discounted cash flow models (DCF); and transient information such as Series A/B/C/D+ funding rounds and corporate valuations. I have utilized semi-public databases like Cruchbase and LinkedIn. Furthermore, I have also reviewed U.S. government documents, financial statements, audits, and reports in contrasting how government contracting currently differs from the entrepreneurial and commercial businesses mentioned above. Such data is available from the Government Printing Office (GPO), Federal Depository Library Program (FDLP), and System for Award Management for searching official publications, budgets, reports, financial documents, procurement details, tangible assets, and other quantitative information.

Secondly, I have utilized important internet sources for my research. Through company. mission documents, press releases, and reports from emerging firms, I can better infer the intent of these firms and understand the trajectory of their envisioned product designs. Numerous, professional articles, presentations, and podcasts have also provided me with meaningful substance in understanding how defense technology was previously developed with the government reforms in the 1960s.

Lastly, my own professional experiences have shaped my perspective on government bureaucracy in defense. After working for three months at a leading unmanned aircraft manufacturer in Southern California, I witnessed firsthand many of the negative effects of current government contracting and bureaucracy. To obtain a more qualitative approach to my research, I have also pursued interview methods that provide valuable anecdotal information from engineers and employees. These interviewees were with the following individuals: (1) J. Hammers. (maintaining confidentiality of full name) who was a successful co-founder of Oculus VR alongside Palmer Luckey who now works as a mechanical and software engineer in product design (PD) for Anduril Industries; (2) Natalia Zeller-M., a recent Master’s of Engineering graduate from Cornell University working at Relativity Space; (3) Thomas G., a graduate of UC Davis working at Joby Aviation as an hardware autonomy engineer; and (4) my boss of my previous employer who has 22 years of experience in defense contracting and is a veteran engineering manager. My interview questions encouraged the respondents to comment on industry trends they foresee, engineering talent that has circulated in their local work environments, personal experiences under their business model, and the quantity of technical project work/ownership available to engineers. While these candidates offer valuable insights, their perspectives have limitations. Unfortunately, I could not interview anyone from the United States government who might have shed light on the old business model's justifications or explained why it resists reform.

Analysis

The utility of AI and machine learning in defense has skyrocketed as there have been dozens more discoveries of the applications of such a technology. The implementation of AI in defense product operation is its most common form of application. Unmanned autonomous systems have been in development for years, but it hasn't been until recently that those systems can purely identify threats themselves. New software systems can operate as a "command hub for a [vehicle] system. They utilize AI and computer vision to depict a view of the battlefield which can be interacted with using a computer, tablet, and [in some cases] VR headset" (Bello, 2022; Hammers., 2023). Every object in the locality of the dynamic vehicle body can be detected, tracked, and classified, whilst the software simultaneously makes automated decisions. Surveillance and reconnaissance can easily be performed while the vehicle adapts to changing conditions and circumstances in the battlefield. Examples of the newest and highly sophisticated vehicles include extremely small and nibble unmanned aircraft (UAV), autonomous underwater vehicles (AUV), or even static structures like sensors or towers (see Figure 1). These vehicles differ significantly compared to the standard technology utilized for the past twenty years, such as single, large-scale, remotely operated "drones" and piloted fighter aircraft.

Figure 1: Left, Anduril Industries' advanced *GHOST* autonomous sUAS (Pondella, 2020). Right, Shield AI's V-BAT vertical-takeoff-or-landing (VTOL) UAS (Tseng 2023).

Secondly, one of the more recent novel developments in AI has been through the development of generative design. Before a product is fully designed, its parts and subsystems must be highly optimized technology. Hardware like complex aircraft structures, aerodynamics, internal components, and other tangible vehicle systems are optimized using multidisciplinary algorithms by cloud computing and AI software (Foster, 2022). Engineers can define requirements for the model (i.e., loading scenarios, constraints, manufacturing processes, and other parameters) and have the software autonomously develop thousands of desirable designs that are more advanced than any human design.

Through these tremendous capabilities, it is apparent that the rapid emergence of AI and machine learning technologies is disrupting the conventional methods to defense innovation. Few regions in the country can match the pace of advanced software development seen in Silicon Valley, and the conventional defense contracting and methods for developing defense technologies cannot compete—the high-tech bubble has set a precedent that defense firms are beginning to follow. Corporations like Tesla, Apple, Waymo, Cruise, Amazon, and Microsoft have led the charge in AI and/or autonomous vehicle development, and dozens of defense startups have rooted their products in the same technological foundations of these hyper-successful monopolies (Wolfe 2022). These startups and growth firms include Anduril, Shield AI, Aerovironment, Dive Technologies, Firestorm, and more. These small, non-traditional defense firms are more willing to fund the development of complex systems primarily at their own expense by securing privatized investments in exchange for the opportunity to win lucrative downstream production contracts. This implies that the DoD could be benefitting from committing to commercial-based competitions for those contracts, resulting in cost-savings and accelerated delivery times. Eric Horan – a contracting officer with over 15 years of experience in defense for the Secretary of Defense and Naval Sea Systems Command (NAVSEA) – summarizes the new contracting landscape of these small firms:

> Emerging technologies like Additive Manufacturing, AI/ML, and Digital Engineering are already here, and are being leveraged by uniquely capable startups to change traditional development paradigms. This enables them to lean forward and assume more risk in development...But they can't do so without understanding the Return on that Investment—the production contract. It shows the massive value in potential cost savings and accelerated delivery timelines that the DoD can achieve by committing to run commercial based competitions for lucrative production contracts. (Horan, 2023).

In other words, a more proactive approach can be taken, allowing these firms to create innovative solutions that are not possible using traditional methods. Although revenues of these startups have remained relatively low (for example, the fastest growing firm hit $10M within its first 20 months and $150M by 2021), individual contracts are projected to provide billions in the next decade (Bello, 2022).

Shifts in talent from Silicon Valley and top engineering universities have quickly accelerated towards defense in recent years. This shift has been fueled by a combination of factors, including the increasing sophistication of emerging technologies and the appeal of working on projects with a clear and accelerating mission. At the fastest-growing defense startup (Anduril), 68% of the technical employees have advanced degrees in computer science, electrical engineering, and software engineering-related fields, while the rest are mechanical engineers—most of this group hails from leading universities such as MIT, Georgia Tech, Cornell, MIT, Stanford, and Berkeley. Besides overall company headcount growth of 171% in the two years and 22% in six months, engineering headcount increased by 61% in one year with those same engineers coming from the San Francisco Bay Area (including Palo Alto, Cupertino, Mountain

View, etc.) (Anduril Industries, 2023). As mentioned from an employee at Anduril, “there’s no reason an engineer designing VR headsets for Oculus or Facebook [Meta] couldn’t join us and develop UAVs.” He argued that, in fact, their human-machine interface experience and creativity in product design makes them superior candidates, as opposed to “tenured” defense engineers in industry for 20+ years (Hammers., 2023). Similar firms have seen impressive headcount growth, with 130% increases in two years, and engineering headcount rising upwards of 45% among numerous firms of 100+ employees (Shield AI, 2023). “This past year, we received over 10,000 applications for a software engineering internship—and only one Level III [junior] student got an offer,” said Natalia Zeller-M., a Cornell graduate and entry-level engineer at Relativity Space. “People follow these new technologies like additive manufacturing and AI, and they feen over the hot-and-coming defense and aerospace startups that utilize these tools” (Zeller-M., 2023).

One might conclude that because these startups are growing and receiving an abundance of capital, their growth and attraction to the highest-level software engineers is inevitable. Although partially true, similar recent trends can be observed at the largest privately funded conglomerates. Palantir, a large software company that provides data analytics solutions to the defense and intelligence communities, has expanded operations and increased engineering headcount by 54% in two years. Most notably, Palantir was founded over 20 years ago and underwent an initial public offering (IPO) in 2020 as an established 4000+ employee company—a true dichotomy of a startup. Hundreds of recent engineering hires come from Stanford and Berkeley, making these two universities its primary sources of technical talent for Palantir’s operations in the United States (Palantir Technologies, 2023). So, although defense startups could be bringing the best software engineers to market *naturally*, large, privately funded defense firms like Palantir still reflect the same trends and demonstrate the true potential a new form defense innovation. It is therefore worth noting that the potential for defense innovation extends beyond just startups, and even established companies are capable of driving innovation in this sector with these sweeping industry changes.

VC firms are beginning to invest in defense technology incorporating AI more than ever, suggesting the great potential qualified investors see in products with this next-generation technology. As background on privatized funding, funding rounds for tech startups are a way of raising capital to finance a tech startup's growth. In each round, the company offers a percentage of its equity in exchange for investment from investors. The earliest round is typically the "seed" round, in which the company seeks small amounts of capital from angel investors or VC firms. As the company grows, it seeks larger amounts of capital in subsequent rounds (such as Series A, Series B, and so on). In the case of defense firms, a funding round typically allows the company to achieve key milestones rapidly, like launching new products, expanding market share, and scaling manufacturing/R&D operations.

In 2022 alone, there has been $7B invested in VC-backed aerospace and defense companies through mid-October; and in 2021, the sector reached a "record deal value of $7.6B" (Temkin, 2022). The top five startup defense firms utilizing AI indicated a total funding amount of over $5.0B since 2017 and 157 total deals by 2019 – a significant milestone in privatized defense funding (Crunchbase, n.d.). Companies like Anduril, Shield AI, and Epirus alone have seen funding growth rates upwards of 960% since seed-round funding and 50% since Series A rounds in just a matter of years, now accumulating to multimillion/billion-dollar individual Series E rounds (Crunchbase, n.d.). Using a discounted cash flow (DCF) model and other VC-startup valuation methods, the top two defense growth firms have a net present value (NPV) of over $11B in just seven years since their founding (Prabhu, 2022). An NPV calculates the present value of all expected future cash flows from investments (like revenue), discounted back to the present using an appropriate discount rate. For perspective, typical growth rates for an average tech/SV startup (and many unicorns) do not approach these growth rates/valuation magnitudes.

The application of Actor-Network Theory is highly relevant in the context of AI and machine learning in defense and the interactions with various actors. Using this framework, the complex networks of relationships can be simplified an understood more effectively. One can examine the role of VC firms in financing defense startups and enabling them to leverage emerging technologies like AI and machine learning. The framework provides a captivating snapshot in time and illustrates how winning downstream production contracts play a key role in securing capital and performing effective product development (a complex process that is black-boxed). Groups of human actors can be combined and mapped into the flow of the network and demonstrate how emerging technologies are crucial for synthesizing innovative defense technologies. One can easily examine that in the absence of startup and growth firms, private investors, capital, and rapid funding severely inhibit the customer's (DoD) ability to receive a desired technology quickly and effectively—and more importantly, that technology may not be innovative or no longer effective in the current battlefield. Refer to the diagram on the page below.

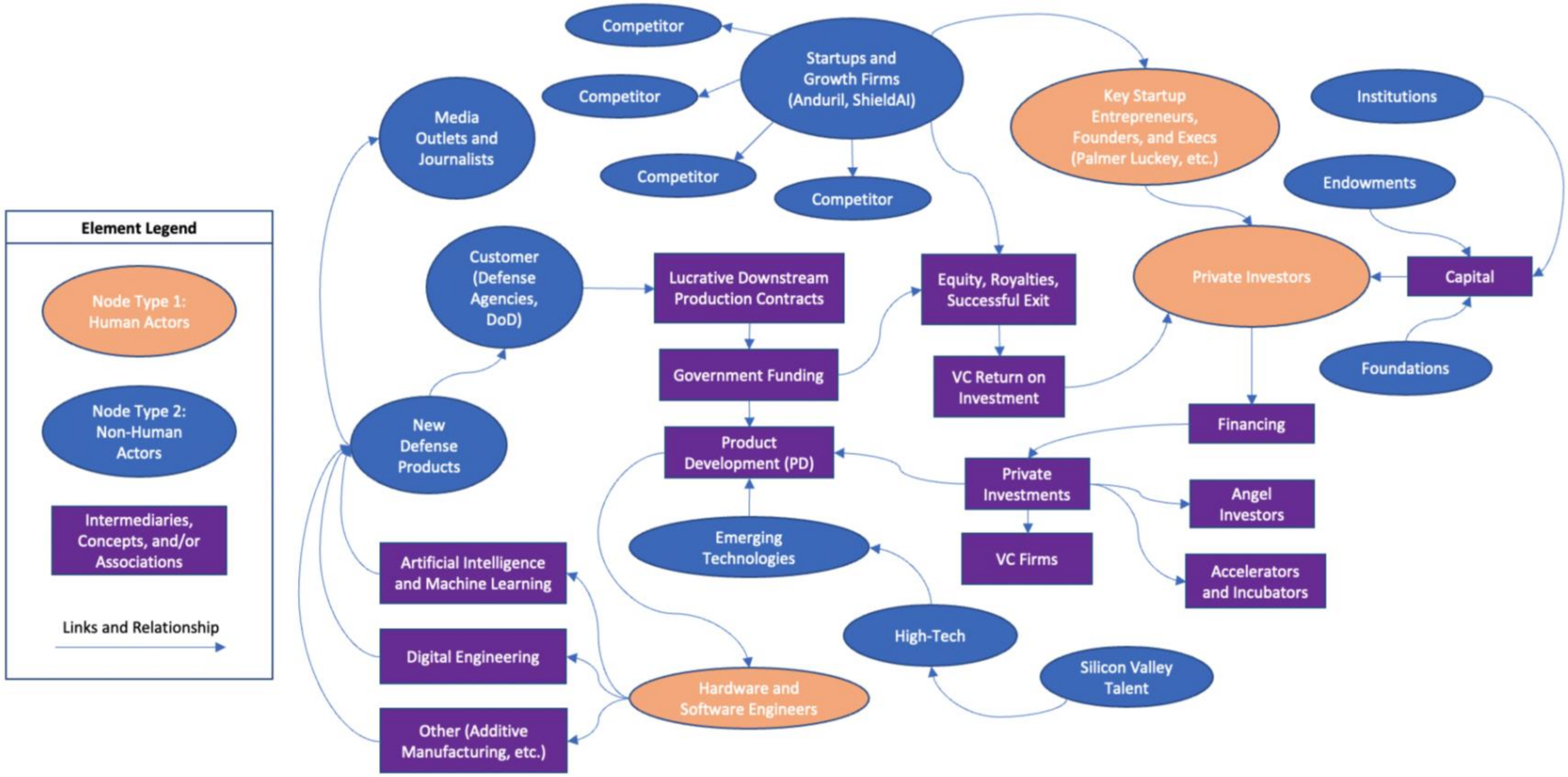

Figure 2: Actor-Network Theory Framework applied to current defense industry shifts.
By C. Tilney-Volk, 2023.

Conclusion

Although the U.S. has been a dominant force in military technology development, it's crucial to continue adapting to new breakthroughs in technology – like AI and machine learning – to innovate effectively. Defense startups are successful from their fixation on digital technology and the agility of software development from high-tech—not just building another missile for the DoD. This research could provide a new outlook into changing how R&D, contracting, and other processes are performed, this includes funding models, organizational structures, awarding contracts, spending, talent acquisition, company culture, acquisitions, and additional black boxes. This research is also imperative for individuals like investors, engineers interested in working on these systems, entrepreneurs, executive-level teams at established defense firms, and other human and non-human actors. As more information and data will be revealed in the coming years, future research should pursue a more analysis that better assesses if my argument and predictions are sufficiently supported. This could include company growth, product effectiveness, and if (most importantly) traditional defense firms and organizations begin to change their methods of R&D. I am fascinated to see how the reforms in the next decade following the rapid growth of AI, and I am hopeful that my research shines a light onto renovating the broken system of innovation in this country.

References

Anduril. (n.d.). In Crunchbase. Retrieved March 15, 2023, from https://www.crunchbase.com/organization/anduril

Anduril Industries (n.d.) [LinkedIn Premium Insight page]. LinkedIn. Retrieved April 1st, 2023, from https://www.linkedin.com/company/andurilindustries/insights/

Anonymous. (2011, September 27). Development of the Lockheed Martin SR-71 Blackbird | Central Intelligence Agency (Foia. CIA. gov). (n.d.). Retrieved March 15, 2023, from https://www.cia.gov/readingroom/document/cia-rdp90b00170r000100080001-5

Arraf, J., & Schmitt, E. (2021, June 4). Iran's Proxies in Iraq Threaten U.S. With more Sophisticated Weapons. *The New York Times*. Retrieved from https://www.nytimes.com/2021/06/04/world/middleeast/iran-drones-iraq.html

Bello, N. (2022, September 14). Anduril Industries Business Breakdown & Founding Story. Contrary Research. Retrieved March 15, 2023, from https://research.contrary.com/reports/anduril

Berenson, D.; Higgins, C.; Tinsley, J. (2021, January 13). The U.S. Defense Industry in a New Era. Retrieved October 27, 2022, from War on the Rocks website: https://warontherocks.com/2021/01/the-u-s-defense-industry-in-a-new-era/

Brose, C. (2020). *The Kill Chain: Defending America in the Future of High-Tech Warfare.* Hachette Books.

Courage to Learn: Defense & Aerospace. (n.d.). Retrieved October 27, 2022, from American Economic Liberties Project website: https://www.economicliberties.us/our-work/courage-to-learn-defense-aerospace/

Cressman, D. (2009). A Brief Overview of Actor-Network Theory: Punctualization, Heterogeneous Engineering & Translation. Simon Fraser University.

Hammers., J. (2023, January 6). Interview with ex-Oculus, Anduril Engineer [Personal communication].

Horan, E. (2023, February 1). Contract Management: The Disruptive Potential of FAR Part 12. Decisive Point. Retrieved March 15, 2023, from https://www.linkedin.com/feed/update/urn:li:activity:7036816924915171329/?updateEntityUrn=urn%3Ali%3Afs_feedUpdate%3A%28V2%2Curn%3Ali%3Aactivity%3A7036816924915171329%29

Epirus. (n.d.). In Crunchbase. Retrieved March 16, 2023, from https://www.crunchbase.com/organization/epirus

Ewalt, D. M. (n.d.). Palmer Luckey: Defying reality. *Forbes*. Retrieved March 15, 2023, from https://www.forbes.com/sites/davidewalt/2015/01/05/palmer-luckey-oculus-rift-vr/

Foster, Q. (2022, October 10). Applying Generative Design to Aerospace. Siemens. Retrieved March 15, 2023, from https://blogs.sw.siemens.com/thought-leadership/2022/10/10/applying-generative-design-to-aerospace/

Future of Defense Task Force Releases Final Report. (2020, September 29). Retrieved October 27, 2022, from House Armed Services Committee—Democrats website: https://armedservices.house.gov/2020/9/future-of-defense-task-force-releases-final-report

Goehle, B. J., Robert Chwalik, and Brad. (2018, October 30). What the top innovators get right. Retrieved October 27, 2022, from Strategy+business website: https://www.strategy-business.com/feature/What-the-Top-Innovators-Get-Right

Insinna, V. (2021, December 21). Silicon Valley warns the Pentagon: "Time is running out." Retrieved October 27, 2022, from Breaking Defense website: https://breakingdefense.com/2021/12/silicon-valley-warns-the-pentagon-time-is-running-out/

Maucione, S. (2015, November 9) DoD's Kendall wants more Research Spending from Industry. Federal News Network. https://federalnewsnetwork.com/defense/2015/11/kendall-wants-research-spending-industry/

Palantir Technologies (n.d.) [LinkedIn Premium Insight page]. LinkedIn. Retrieved April 1st, 2023, from https://www.linkedin.com/company/palantir-technologies/insights/

Pondella, C. (2020). Anduril's Ghost 4 ISR Drone. Anduril. Retrieved March 15, 2023, from https://www.forbes.com/sites/erictegler/2020/09/11/andurils-new-isr-drone-looks-like-a-helicopter-not-surprising-since-cofounder-palmer-luckey-flies-his-own-uh-60-black-hawk/

Prabhu, A. (2022, December 2022). Palmer Luckey's Defense Startup Snaps $1.48B, Doubles Valuation Reaching at $8.48B. Retrieved March 15, 2023, from TechFundingNews website: https://techfundingnews.com/oculus-designer-palmer-luckeys-anduril-snaps-1-48b-doubles-valuation-reaching-8-48b/

Rao, B., Gopi, A. G., & Maione, R. (2016). The Societal Impact of Commercial Drones. *Technology in Society*, 45, 83–90. https://doi.org/10.1016/j.techsoc.2016.02.009

Servan-Schiber, J. J. (1968) *The American Challenge* (1st ed.). New York, NY. Pelican (Penguin) Books.

Shield AI. (n.d.). In Crunchbase. Retrieved March 15, 2023, from https://www.crunchbase.com/organization/shield-ai

Shield AI (n.d.) [LinkedIn Premium Insight page]. LinkedIn. Retrieved April 1st, 2023, from https://www.linkedin.com/company/shield-ai/insights/

Stephens, T. (2022, June 6). Rebooting the Arsenal of Democracy: Anduril Mission Document. Retrieved October 27, 2022, from Medium website: https://blog.anduril.com/rebooting-the-arsenal-of-democracy-anduril-mission-document-67fdbf442799

Stone, J. R., Madeline. (n.d.). How 24-year-old Palmer Luckey went from Selling his VR Startup to Facebook for $2 Billion to Building a Virtual Border Wall. *Business Insider*. Retrieved March 15, 2023, from https://www.businessinsider.com/palmer-luckey-life-career-of-ousted-oculus-vr-founder-who-sold-startup-to-facebook-2-billion

Temkin, M. (2022, October 26). VCs go outside their comfort zone with bets on Defense Tech. Retrieved from PitchBook website: https://pitchbook.com/news/articles/defense-space-vc-ukraine-recession

The Skunk Works® Legacy. (2020, April 30). Retrieved October 27, 2022, from Lockheed Martin website: https://www.lockheedmartin.com/en-us/who-we-are/business-areas/aeronautics/skunkworks/skunk-works-origin-story.html

Tseng, R. (2023, January 17). V-BAT: A Gold Standard for Architectural Excellence. Retrieved March 15, 2023, from Shield AI website: https://shield.ai/v-bat-a-gold-standard-for-architectural-excellence/

Whitney, J. (2021, April 26). Artificial Intelligence and Machine Learning for Unmanned Vehicles. Military Aerospace. https://www.militaryaerospace.com/unmanned/article/14202040/artificial-intelligence-and-machine-learning-for-unmanned-vehicles

Wolfe, J. (2022, February 5). The Rise of Defense Tech is Bringing Silicon Valley back to its Roots. *TechCrunch*. https://techcrunch.com/2022/02/05/the-rise-of-defense-tech-is-bringing-silicon-valley-back-to-its-roots/

Zeller-M., N. (2023, March 2). Interview with Cornell Engineering Graduate and Relativity Space Engineer [Personal communication].