DEFENDING U.S. AND ALLIED AIRSPACE UTILIZING MASS-PRODUCED DRONE INTERCEPTOR TECHNOLOGY

ANALYSING THE DEVELOPMENT OF POST-TRAUMATIC STRESS DISORDER IN U.S. ARMY DRONE OPERATORS DUE TO SOCIO-POLITICAL FACTORS

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of The
School of Engineering and Applied Sciences
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Aerospace Engineering

By Matthew Shin

November 30, 2024

Technical Team Members:
Nora Wilkerson, David Wiles, Savannah Hafer, Reid Smith, Will Couch, Evan Hahn, Agha Mohammad Ali, Eric Fryer

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

Advisors
Kent Wayland, Department of Engineering and Society
Thomas Ward, Department of Mechanical and Aerospace Engineering

Introduction

How Can National Security be Improved Through the Use of Improved Drone Technologies and Operational Practices?

As global conflicts such as the war in Ukraine and Taiwan escalate and as tensions between the United States and countries such as China and Russia continue to become more strained (Silver, 2022), the need for an effective national security response is more important than it has been in decades. As foreign nations continue to bridge the technological gaps between themselves and the U.S., further development of countermeasures that can counter these threats is a priority to ensure the safety of the nation and its allies. This necessity for increased homeland protection is the primary technical focus of this project. Together with a team of eight other undergraduate students, we propose the creation of a fleet of effective and affordable drone interceptors to protect United States and allied soil. This fleet will be designed to perform a variety of defense interception missions and counter current and next generation missiles and bombers which could be used offensively against us and our allies. While technological advancements are an important part of increasing U.S. security, another dimension that has been historically overlooked must be addressed in tandem with technological developments to increase the effectiveness of military personnel and reduce the social impact of PTSD that arises when soldiers return from conflict. This problem is especially important to consider when discussing the use of drone technology, which introduces new methods of engagement and differing contexts from conventional boots-on-the-ground warfare.

Taking both of these problems into account, this project will focus both on the practical creation of a fleet of mass-produced drone interceptor aircraft, which would fill gaps in U.S. air defense, as well as an in-depth analysis of the factors that contribute to the development of PTSD in drone pilots including direct causes, indirect social factors, and possible solutions.

Defending U.S. and Allied Airspace Utilizing Mass-Produced Drone Interceptor Technology

The United States' stealth-centric fleet, comprising the F-22 and F-35 aircraft, is projected to retire in the 2030s (Kass, 2024). This fleet has been instrumental in defense missions against increasingly sophisticated and advanced enemy air systems. Addressing this imminent capability gap requires the development of a small, high-performance, cost-effective, and efficient unmanned homeland defense interceptor.

Escalating global political tensions heighten the risk of aerial attacks on the United States, making the deployment of effective aerial defense technologies crucial for national security (AIAA, n.d.). As the retirement of a significant portion of the current Air Force fleet approaches, innovative air warfare advancements are essential to safeguard the nation's future. The homeland defense interceptor is poised to fill this critical role, designed to match and exceed the performance of its predecessors while advancing airspace control and defense capabilities.

Through collaboration with the American Institute of Aeronautics and Astronautics (AIAA), our group aims to design a next-generation aircraft for the United States military, surpassing the current fleet's capabilities. Key requirements include maintaining a unit cost below $25 million and offering the versatility to conduct multiple mission types as specified by the AIAA. The aircraft must effectively perform point-defense interception, defensive counter-air patrol, and intercept/escort missions and should meet essential criteria for performance. By meeting and exceeding these standards, the design will enhance homeland defense against intercontinental ballistic missiles and long-range bombers.

To commence the design phase, the team performed a thorough analysis of contemporary military defense aircraft, specifically examining the Lockheed Martin F-22 and F-35. These aircraft were engineered with a focus on stealth and interception, incorporating “low probability of detection/intercept” features that were pivotal for maintaining air-to-air superiority during the Global Strike Task Force era (Everstein, 2018). Our current objective is to extend this air-to-air dominance, now integrating effective remote functionalities. The design framework has been organized into distinct system subteams: propulsion, avionics, aero-body, structural elements, and integration/testing, ensuring alignment with specified parameters.

The propulsion system will include the engine, intakes, engine mount, and a thermal control system, consuming a significant portion of the mass budget. Avionics will encompass the remote pilot system, weapons deployment, flight control systems, and overall power requirements for the aircraft. The aero-body will involve aerodynamic elements such as the wing, stabilizer, fuselage, intake, and control surface designs. The structural subsystem, responsible for supporting all components, will feature the airfoil, fuselage framework, landing gear, payload bay, and maintenance access hatches. Integration and testing will cover the final design development, total mass distribution, fuel weight, and maneuverability impacts, non-electric equipment considerations, and overall subsystem integration. These subsystems are interconnected, requiring strong collaboration among system subteams to achieve seamless performance. With strict design constraints and a limited budget, an in-depth analysis of each subsystem component ensures compatibility and cost efficiency. This subsystem-driven approach allows for precise resource management while delivering a comprehensive and cohesive aircraft design.

In addition to a technical design, the project involves developing a digital 3D model of the aircraft, accompanied by an analysis of cost, risk, and the strategic placement of subcomponents such as fuel tanks, payload, engines, weapons, and piloting avionics. Aircraft design inspiration will draw from a wide range of historical and modern references. See Figure 1 below for the preliminary conceptual design of the HDI24 aircraft. These references will include government reports, research studies on aircraft like the F-22 and F-35, specifications of payload and equipment, advancements in emerging technologies, and insights from technical advisors. The model will be created using three design tools. Solidworks will be used to build the 3D aircraft model. OpenVSP will perform basic fluid dynamics simulations for lift and drag

analysis. Finally, ANSYS Mechanical will simulate the structural loads experienced by the aircraft during operations.

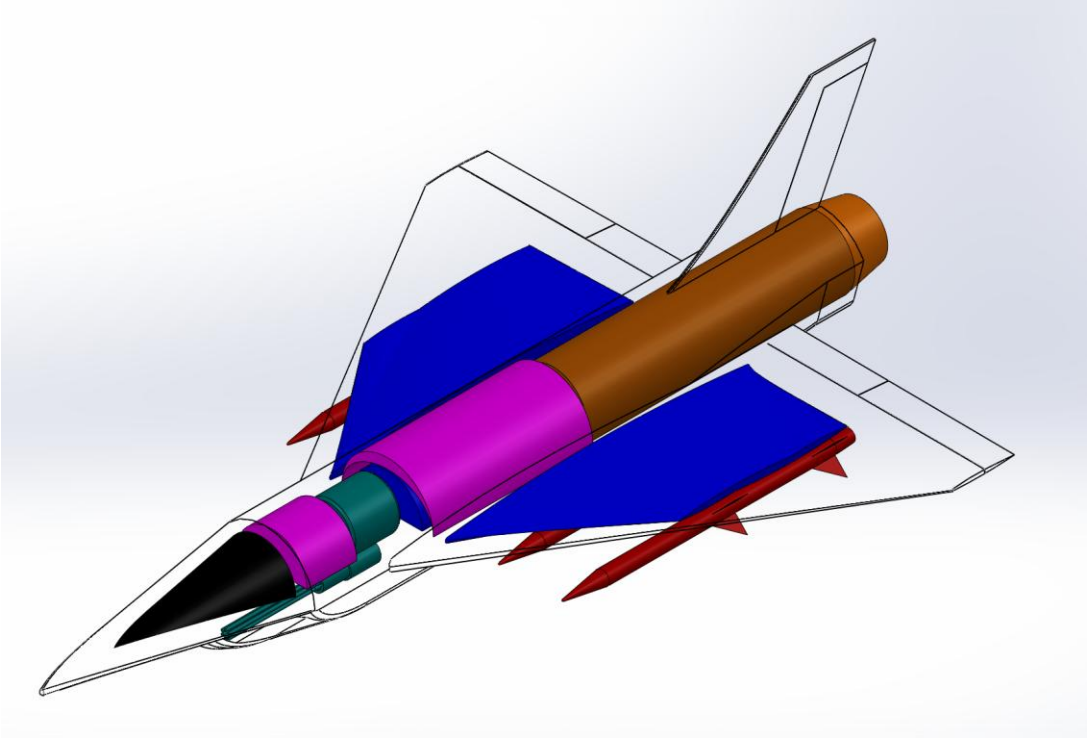

Figure 1: The Aeronautics Autonomous HDI24 Aircraft 3D Conceptual Design created using SOLIDWORKS.

Through the completion of this technical project, we want to create a high-performance, cost-effective drone that could be used as an effective countermeasure against ballistic missiles as well as current and future generations of bomber aircraft that may threaten our home soil. As the use of drones in warfare becomes more prevalent, we hope that the research done on this project could serve as a basis for further development of supersonic drone aircraft in the future.

Analyzing the Socio-Political Factors Contributing to the Development of Post-Traumatic Stress Disorder in U.S. Air Force Drone Operators

How Can We Mitigate the Development of PTSD in Drone Operators Through Analysis of Unique Operational and Societal Pressures?

Despite the large role that military personnel play in the defense and security of their countries, the effect of war on these individuals has been historically overlooked by the governments and societies that they work to protect. Post-traumatic stress disorder has only been a diagnosis since 1980 (Friedman, 2022), and resources for affected individuals are often lacking and ineffective, around two-thirds of military PTSD patients remain with the condition even after treatment (Levi, Yahude, Pine, & Bar-Heim; 2022). This is compounded by an underlying

collective societal ignorance of the mental problems experienced by soldiers and social stigma which can cause veterans to refrain from treatment altogether (Roscoe, 2020). As there is no current FDA-approved medication for PTSD (Richman, 2022) and current treatment methods prove ineffective, the most reliable way to prevent this issue is to understand the underlying causes that factor into its development. With the introduction of a new type of warfare, through the use of drones and remote weaponry, we need to consider the unique challenges that have and will arise concerning the mental well-being of the soldiers utilizing them. Looking at this topic through an STS lens must take into account a variety of different social groups, including the government, military, citizenry, and the operators themselves and their interpretations of drone technology as well as how these interpretations have a tangible effect on the conditions and context which drone operators work under. Through this analysis, I hope to answer the question, "How do these different social groups directly and indirectly affect the operational and societal stresses that are unique to USAF drone operators and how can these effects lead to the development of PTSD?"

Background and Analysis of Current Literature

Although drone pilots experiencing PTSD may seem unbelievable at a glance compared to their contemporaries who are actively serving in combat zones, it is important to realize that drone operators do experience PTSD to a similar level to pilots of manned aircraft. According to known research, groups experience similar levels of PTSD at around 3-6% (Wood, 2018). Some factors such as participating in the act of killing and the death of civilians also contribute to the development of PTSD in both groups. Additionally, similar symptoms are experienced by both groups using the standards of the PTSD Checklist-Military Version (PCL-M) (Wood, 2018).

Although there are similarities in how these groups experience PTSD, recent studies have shown that there exists a large difference in the severity of several operational factors that can influence the development of PTSD. For example, drone pilots experience extremely long working hours, during missions, shifts can be 24 hours a day (Saini, 2021). This can adversely affect their sleep, decision-making, and levels of operational stress in comparison to pilots of manned aircraft (Nesthus & Fercho, 2021) who generally pilot their vehicles for much less time. Additionally, they often see much more graphic imagery of violence in the aftermath of battles due to the nature of their jobs and the technology. While manned aircraft pilots usually strike and leave quickly, drone pilots often visually observe their targets for long periods of time and see the aftermath of strikes in order to confirm that their target was hit (Johnston, & Eckert, 2022). Compounded with the use of high-definition cameras on many of these UAV-type aircraft, this can cause extreme mental stress and lasting images of violence which can contribute to the development of PTSD.

Separate from operational factors, there are societal factors that can affect drone pilots as well. The politicization of the conflicts in which they are involved can adversely affect their

personal perception of their actions. Additionally, their own citizenry can place judgment on them for actions that they took during wartime (Sagan & Valentino, 2019) which can lead to a lack of emotional support and guilt once they return home.

Theoretical Framework

In order to understand the development of PTSD in drone operators, I would like to look at the problem through the lens of different social groups and how their policy decisions and/or personal beliefs can lead to the previously described factors that contribute to this development. The SCOT theory of thought emphasizes how different social groups attach different views to the same type of technology, which in turn affects how the technology is used and developed (Pinch & Bjiker, 1984/2012). In the context of how drone technology is developed and used and how this psychologically affects drone pilots, there are 5 main social groups that I would like to analyze: Congress and the president, Air Force command, the U.S. citizenry, and the drone operators themselves. For Congress, the president, and Air Force command, I would like to examine how their views affect policy decisions surrounding drone operations and development for warfare. For the citizenry and the drone operators, I would like to primarily focus on how their views can create and contribute to the stigma against the technology as well as the social and moral stresses that affect drone operators.

Methods: Evidence/Data Collection and Analysis

I plan to collect data from a variety of sources in order to fully understand the context and effects each of these groups has in the overall system which contributes to the development of PTSD in drone operators within the USAF. I would like to: research further ways that U.S. military doctrine affects drone operators through a variety of military reports concerning operational practices in conflict situations, study Congress's and recent presidents' policy decisions concerning drone warfare primarily through the analysis of political journals and government statements, and dive in-depth into how public opinion on drone warfare has changed throughout the last two decades through the use of surveys of U.S. citizens and study of media coverage surrounding drone warfare. Through in-depth analysis of these sources, I will work to understand to what level each of the outlined social groups contributes to the different factors in PTSD development in drone operators and identify areas in which positive change could be made.

Conclusion

In conclusion, this project's aim is to analyze drones as a technology, their use, and implications, in order to improve the effectiveness of our national security through both technological means and analysis of underlying social and psychological issues that affect the operators who pilot them. The technical portion of this project is focused on developing drone technologies to fill a wider range of roles in order to improve the capabilities of the United States to defend itself against any foreign attacks. The STS portion of this project is focused on how we can improve the mental health of the operators of this technology through analysis of how the policies and beliefs of different social groups contribute to the factors that lead to the development of PTSD in drone operators. In addition to understanding how these social groups contribute to these factors, I also hope to glean insight into possible solutions that could mitigate the problem. In conjunction, these should lead to a national defense that is generally more functional in a technological and operational capacity.

References

American Institute of Aeronautics and Astronautics [2] . (n.d.). Homeland defense interceptor request for proposal. Retrieved October 25, 2024, from https://www.aiaa.org/docs/default-source/uploadedfiles/membership-and-communities/university-students/design-competitions/2024-2025-undergraduate-team-homeland-defense-interceptor.pdf?sfvrsn=83907eb9_10

Everstein, B. W. (2018, January 29). The F-22 and the F-35 Are Struggling to Talk to Each Other ... and to the rest of USAF. Air & Space Forces Magazine. https://www.airandspaceforces.com/article/the-f-22-and-the-f-35-are-struggling-to-talk-to-each-other-and-to-the-rest-of-usaf/

Friedman, M. (2022, October 6). *PTSD History and Overview*. National Center for PTSD. https://www.ptsd.va.gov/professional/treat/essentials/history_ptsd.asp

Johnston Huntington, T., & Eckert, A. E. (2022). 'We watched his whole life unfold. . .Then you watch the death': drone tactics, operator trauma, and hidden human costs of contemporary wartime. International Relations, 36(4), 638-657. https://doi.org/10.1177/00471178221135036

Kass, H. (2024, June 21). The Air Force's F-22 fighter nightmare has just started. *The National Interest*. https://nationalinterest.org/blog/buzz/air-forces-f-22-fighter-nightmare-has-just-started-211549

Levi, O., Ben Yehuda, A., Pine, D. S., & Bar-Haim, Y. (2022). A Sobering Look at Treatment Effectiveness of Military-Related Posttraumatic Stress Disorder. Clinical Psychological Science, 10(4), 690-699. https://doi.org/10.1177/21677026211051314

Nesthus, T. E., & Fercho, K. A. (2021, May). *Summary Final Report for Unmanned Aircraft Systems in Air Carrier Operations: UAS Operator Fatigue*. FAA | Publications. https://www.faa.gov/sites/faa.gov/files/data_research/research/med_humanfacs/oamtechreports/202116.pdf#:~:text=This%20report%20focuses%20on%20operator%20fatigue%20and%20how%20fatigue%20factors

Pinch, T. F., & Bijker, W. E. (1987). The Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. In W. E. Bijker, T. P. Hughes, & T. F. Pinch (Eds.), *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology* (pp. 17–50). MIT Press.

Richman, M. (2022, April 25). *Study: economic burden of PTSD "staggering."* VA Research Currents. https://www.research.va.gov/currents/0422-Study-economic-burden-of-PTSD-staggering.cfm

Roscoe, R. A. (2020). The Battle Against Mental Health Stigma: Examining How Veterans with PTSD Communicatively Manage Stigma. *Health Communication*, *36*(11), 1378–1387. https://doi.org/10.1080/10410236.2020.1754587

Sagan SD, Valentino BA. (2019) Just War and Unjust Soldiers: American Public Opinion on the Moral Equality of Combatants. *Ethics & International Affairs*. 2019;33(4):411-444. doi:10.1017/S0892679419000431

Saini, Rajiv Kumar; V. K. Raju, M. S.1; Chail, Amit2. *Cry in the sky: Psychological impact on drone operators*. Industrial Psychiatry Journal 30(Suppl 1):p S15-S19, October 2021. | DOI: 10.4103/0972-6748.328782

Silver, L. (2022, April 28). *China's Partnership With Russia Seen as Serious Problem for the U.S.* Pew Research Center.

Wood, Ware, Correll, Heaton, McBride, Haynes, Relationship Between Spiritual Well-being and Post-traumatic Stress Disorder Symptoms in United States Air Force Remotely Piloted Aircraft and Intelligence Personnel, *Military Medicine*, Volume 183, Issue 9-10, September-October 2018, Pages e489–e493, https://doi.org/10.1093/milmed/usx032