AIAA Homeland Defense Interceptor Design

Defense and the Aviation Industry
A Thesis Prospectus
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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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In this prospectus, I address the key points of my capstone research, focusing on the main objective of developing a cost-effective, autonomous military interceptor aircraft. The challenges are aimed at reducing costs and limiting reliance on manned aircraft used in combat situations. Traditional military aircraft, such as the Lockheed Martin F-22 and F-35, are very expensive to manufacture and maintain. As the cost of supplying the U.S. military continues to rise, there is an urgent need for new aircraft capable of meeting and exceeding the high standards of current airframes. Cutting costs while maintaining air superiority is essential for the future of combat air operations. My project aims to enhance both operational efficiency and cost-effectiveness.

My STS research focuses on the larger socio technical question of how warfare has historically driven innovation trends, specifically in aviation technology. Since the first flight by the Wright brothers in 1903, aviation has seen rapid development, much of it influenced by manufactured demands caused by foreign affairs. My focus is primarily on American warfare, spanning key conflicts such as WWI, WWII, the Cold War, the Global War on Terror, and the present "new age" of warfare, which increasingly uses remotely piloted vehicles and minimizes ground combat operations. Throughout these periods, militarization has accelerated advancements in aerospace defense technologies, which has transitioned into commercial aviation applications. Still, progression from military to civilian aviation technology is not always an easy transition, as the engineering for defense purposes often introduces multiple ethical, legal, and social considerations.

The connection between the two ideals is in line with the notion that modern military needs drive technological innovation, with potential lasting impacts on civilian projects. As autonomous systems advance in use by the defense sector, their integration into broader aerospace contexts, such as commercial and cargo aviation needs becomes ever more reasonable. My research takes a close look into the dual capabilities of engineering projects, highlighting the multi-use nature of aviation technologies and the responsibilities engineers hold in managing this transition.

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. The production goal is one thousand units, emphasizing cost minimization and the use of government-furnished equipment to maximize affordability and accessibility.

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.

This project aims to design a next-generation aircraft for the United States military, surpassing the current fleet's capabilities. Key requirements are outlined in the tables below, the most important of which are maintaining a unit cost below $25 million and effectively performing point-defense interception, defensive counter-air patrol, and intercept/escort missions.

S-F#	Requirement Title	Evaluation Method
S-F1	Unmanned: must be piloted remotely	Electronics and Controls Selection
S-F2	Take off and land safely	Mathematical Analysis
S-F3	Be operable in all weather conditions	Material selection
S-F4	Complete designated missions	Mathematical Analysis

Table 1: System level functional requirements and evaluation methods

The aircraft should meet essential criteria for performance, weapons carriage, and engine specifications, accommodating all required equipment, weapons, and fuel tanks while facilitating maintenance. By meeting and exceeding these standards, the design will enhance homeland defense against intercontinental ballistic missiles and long-range bombers.

S-O#	Requirement Title	Evaluation Method
S-O1	Able to fly at mach 1.6	Computational Fluid Dynamics
S-O2	Cheaper than $25 million	Financial Budget
S-O3	Service life of 2000+ hours	FEA Fatigue Analysis
S-O4	Possess enough fuel to accomplish missions	Mathematical Analysis
S-O5	Withstand dynamic pressure of 2133 psf	Finite Element Analysis
S-O6	Turn at a rate of 18 degrees/sec at 35000 ft	Stability and Control Analysis
S-O7	Withstand between +7 and -3 g's	Finite Element Analysis
S-O8	Use JP-8 or Jet-A fuel	Engine Selection
S-O9	Operate on an 8000 ft runway	Engine Selection
S-O10	Subsonic Static Margin ± 10%	Stability Analysis
S-O11	Accelerate 26 ft/s^2	Engine Selection

Table 2: System level operational requirements and evaluation methods.

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 components: propulsion, avionics, aero-body, structural elements, and integration/testing, ensuring alignment with specified parameters.

The design 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, engine, 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.

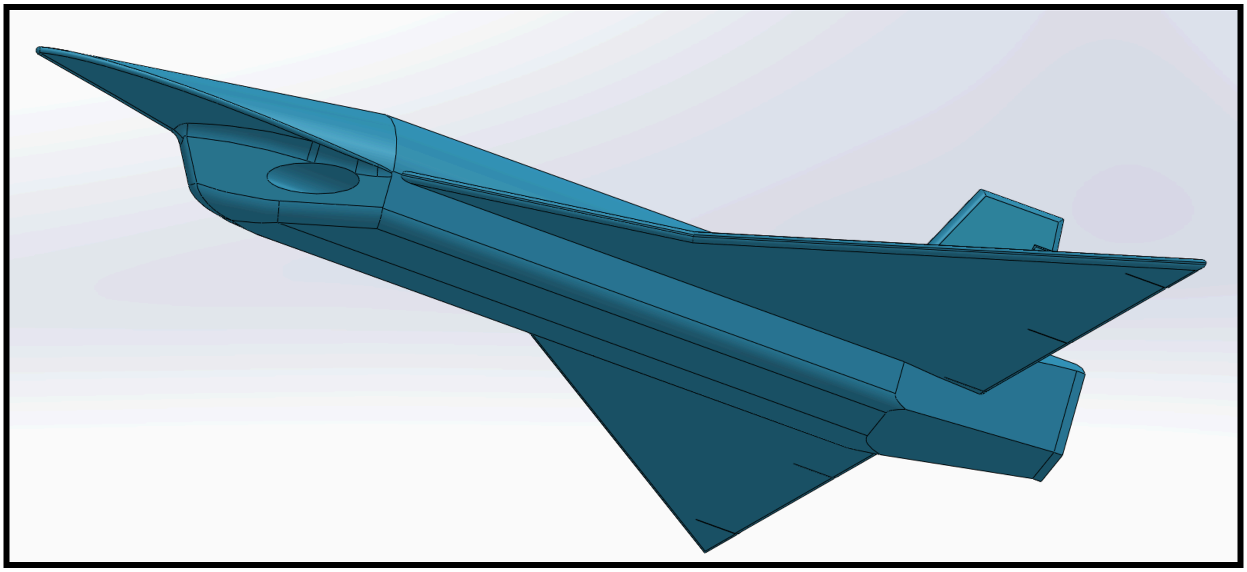

Figure 1: The Aeronautics Autonomous HDI24 Aircraft 3D Conceptual Design created using SOLIDWORKS.

The team will be broken down into subsystems to divide the work among the team members. 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 team will design aerodynamic elements such as the wing, stabilizer, fuselage, intake, and control surface designs. The structural subsystem is responsible for supporting all components, and will design 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 team members to achieve seamless performance. With strict design constraints and a limited budget, 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.

Warfare has historically acted as a powerful catalyst for advancements in aviation technology, as the urgent demands for combat effectiveness drive rapid innovation. Military conflicts fabricate an environment in which national resources are dedicated towards a common goal of developing increasingly advanced technologies. Innovations sparked by conflict often lead to breakthroughs that redefine not only aerospace defense, but also have massive effects on engineering in the civilian sector (Schlager, N., 2016). For instance, during World War II, the need for speed and maneuverability became more significant than ever solely because of air to air combat missions, which led to the birth of the first jet propulsion engine (Murray, J. D., & Reddick, J., 2006). This set a new standard for performance that eventually revolutionized commercial aviation as well, proving that military driven technologies can transform entire industries over time. Similarly, the Cold War, characterized by intense competition mainly between the USSR and the USA, guided innovation in aerospace engineering to a new level. The further development of advanced jet propulsion, missile systems, and satellite technology became important constructs of modern warfare (Sakka, A., 2011). To add to the argument, modern material science, specifically in terms of aviation and aerospace, is a direct effect of conflict and large scale manufacturing of military aviation (Simmons, R. C., & Shubov, M. A., 2004). The large-scale militarization between super powers also gave rise to modern Vertical Takeoff and Landing (VTOL) air frames which are linked to modern helicopter technology (Gedeon, S. A., 2019). These advancements not only bolstered national defense capabilities but also laid the groundwork for the commercial satellite industry and reshaped global communications (Mueller & Svik, 2021). The advancements from the Cold War had a lasting impact on aerospace technology that is still seen today. Again, showing that even in the wake of conflict, military innovations have the ability to influence industries beyond the original intentions.

In recent years, the widespread presence of unmanned aerial vehicles (UAVs) in military operations has become a pivotal role of remote piloted and autonomous systems in aviation. Initially, autonomous machines were strictly used for military surveillance, and now UAVs are capable of contributing to combat operations. The main reason for the transition was to significantly reduce human risk in hostile environments (Simmons, R. C., & Shubov, M. A., 2004). This shift highlights a trend where modern warfare is a catalyst for autonomy, with applications extending into civilian sectors such as disaster response, manufacturing, and logistics. These examples illustrate the transition of military technology and its capacity to drive technological progress beyond combat.

I intend to collect data through a thorough review of historical documents and case studies, focusing specifically on American conflicts since 1903. I will look at technological developments in aviation that emerged during these conflicts, giving teh majority of my attention to primary sources such as military records and patents. Additionally, I will analyze secondary sources, including academic papers and historical analyses from experts in order to understand how wartime needs shaped advancements and influenced post-war civilian applications. Tracking documented advancements in relation to their lasting civilian adaptations I intend to illustrate a clear correlation between conflict and innovation. I am looking to emphasize the interconnected nature is directly correlated with the needs of national militarization. This approach will provide a comprehensive understanding of how military driven technology in aviation has been, and can continue to be, adapted for current and future civilian engineering problems.

In examining military needs and technological advancements in aviation and aerospace, my Capstone Project and STS research will reveal the position that combat operation has in driving innovation. By designing a cost-effective, autonomous military interceptor, my project aims to address critical gaps in defense capabilities as current fleets approach retirement, offering a solution that is adaptable to evolving national security threats. Simultaneously, my research highlights the potential of future aviation technologies, where innovations initially developed for military applications often transition to the civilian sector, raising considerations when it comes to regulating such things. As autonomous systems become increasingly integrated into defense, they not only redefine the capabilities of military aircraft but also hold promise for aerospace applications, from commercial aviation to cargo transport. These advancements require a balanced approach that considers both the benefits and societal implications of such powerful technologies. Using key arguments and historic trends to illustrate the ongoing influence of military demands on aviation technology and the great responsibility of engineers to guide these advancements thoughtfully, knowing that intended use is not the only use.

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