

# **Unmanned Homeland Defense Interceptor**

A Technical Report submitted to the Department of Mechanical and Aerospace Engineering

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

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Spring, 2025

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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

Thomas Ward, Department of Mechanical and Aerospace Engineering

## Introduction

The increasing threat of aerial attacks on the United States necessitates the development of a cost-effective, high-performance autonomous homeland interceptor. As geopolitical tensions rise, ensuring the protection of U.S. airspace is a critical national security priority. However, current fighter aircraft, such as the F-22 and F-35, are too expensive to procure in sufficient numbers for both homeland defense and force projection. Additionally, by 2045, the majority of Air Force and Navy fighter aircraft will reach the end of their service life, underscoring the urgent need for an affordable and capable alternative.

To address this need, the Homeland Defense Interceptor (HDI) is designed as a small, low-cost, high-performance autonomous aircraft capable of securing U.S. airspace while maintaining operational efficiency. Its primary objective is to execute defensive counter-air (DCA) patrol missions, conduct point-defense interception missions, and ensure airspace sovereignty with a fleet of 1,000 aircraft. The mission of the HDI program is to integrate cutting-edge aerospace innovation to develop a reliable, remotely piloted aircraft that enhances national defense capabilities while mitigating industry capability gaps. By leveraging advanced but cost-efficient technologies, the HDI will provide a sustainable solution for future air defense challenges.

Operationally, the HDI will be remotely piloted and deployed from existing military bases, conducting long-endurance patrols and responding to domestic threats with high-speed interception capabilities. The aircraft's unmanned nature allows for increased avionics capacity and greater operational flexibility, enabling it to perform missions beyond the capabilities of manned fighters. By eliminating the need for onboard crew accommodations, the HDI can maximize fuel efficiency, extend endurance, and operate under extreme conditions that might be too risky for piloted aircraft.

The HDI's design prioritizes a balance between performance, maintainability, and cost efficiency. To meet mission requirements, the aircraft must be compact yet structurally durable, capable of achieving Mach 1.6 at 35,000 feet. Additionally, cost-effectiveness is critical, with a target flyaway cost below \$25 million per unit, achieved through the integration of existing government-furnished equipment (GFE). To ensure optimal functionality, the HDI will feature a high-thrust, fuel-efficient engine for sustained performance, compatible weapons systems including AIM-120 missiles and a 20mm cannon, and structural durability rated for +7 to -3 g's with a minimum 2,000-hour service life.

To enhance mission effectiveness, operational design features will focus on rapid maintenance access for quick repairs, self-sealing fuel tanks for increased survivability, and seamless compatibility with existing base infrastructure. However, several key constraints must be addressed throughout the design process. Budget limitations may restrict the integration of advanced technologies, requiring careful selection of cost-effective solutions. A reliable communication infrastructure is essential for secure remote operation, ensuring real-time coordination and control. Additionally, the aircraft's design must strike a balance between stealth, speed, and endurance without exceeding weight or cost limitations.

By overcoming these challenges and adhering to strict performance and cost requirements, the HDI will provide a viable, long-term solution to maintaining national airspace security. Its development represents a critical step toward ensuring the United States remains prepared to counter future aerial threats with a robust and scalable defense system.

## **Program Management**

Aircraft design is complex and iterative, and our team explored multiple approaches before settling on a structured methodology. We began by identifying design requirements, though in hindsight, our initial list was incomplete and required revision as the project evolved. To establish a baseline, we analyzed existing aircraft with similar roles and used mass ratios to develop a starting specification sheet. Each team had considerable autonomy in their design decisions, but without strong initial guidance, collaboration proved challenging, leading to inefficiencies and isolated workflows. Early design iterations were inconsistent, and inaccurate estimates caused delays, resulting in a slow start that impacted later stages of development. Eventually, we aligned on a single design methodology based on Raymer's method in the book *Aircraft Design: A Conceptual Approach* (Raymer, 2006), but adopting it late in the process limited our ability to make major changes. The conceptual design framework provided valuable insights but was difficult to apply at times due to both its complexity and the inherent challenges of aircraft design. Our schedule was largely driven by design review presentations from September to February, though some requirements did not directly contribute to our final goal, leading to inefficiencies. Project management tools like Microsoft Planner were underutilized, complicating organization and task tracking. By February, team leadership took a more active role in driving progress, ensuring that key subsystems, including electronics, structures, and the aerobody, were developed cohesively. While the process was far from perfect, we adapted, learned from our missteps, and ultimately delivered a viable aircraft design that met our project constraints.

## **Aerobody**

The airframe of the HDI-25 interceptor takes into account multiple different design constraints and mission parameters to fulfill the goal of a low-cost, low-maintenance, and high-performance aircraft. The design takes inspiration from multiple different, tested aircraft designs. The overall configuration consists of a delta wing design with dual vertical tail fins and a single engine intake located on the bottom of the aircraft. The total length of the aircraft is 44.7 ft, detailed within Figure 1.3.

The wing configuration that was selected is a cropped delta-wing configuration as seen in Figure 1.1. This configuration was chosen due to the delta geometry's inherent characteristics. This geometry allows for reduced wing loading, allowing for a thinner wing to reduce drag and cost, as well as reduced maintenance requirements. For the airfoil, the NACA 0002 symmetric airfoil was selected due to the need for high angles of attack in takeoff for delta-wing aircraft which can be mitigated by the higher stall angle of attack afforded by a symmetric airfoil design. In order to produce lift for takeoff, a symmetric airfoil requires a positive angle of attack, therefore, the aircraft will be oriented in a pitched-up position when the landing gear is deployed. Further dimensions can be found in Figure 1.3. Four hardpoints are located on the lower side of each wing, which will hold both the missile systems as well as the external fuel tanks, which are

needed for longer-range missions. The wing has an effective area of approximately 450 ft<sup>2</sup> with a wingspan of 33 ft.

A twin-tailed vertical fin design with a 20-degree offset from the centerline of the fuselage was chosen for several reasons. The primary reason for the dual fin design is increased maneuverability; the introduction of an extra control surface allows for sharper correction of yaw. The dual fin design also creates redundancy in the aircraft's design, ensuring that if one of the fins is damaged, the aircraft will still be able to maneuver.

The fuselage design is a fairly standard tube design that blends into the wings in order to reduce drag as well as give more space for fuel near the base of the wings. It houses all the internal systems, as seen in Figure 1.2, which consists of the gun system, the landing gear, the engine, the electronics, and the fuel tanks. The nose cone shape is an ogive cone that maximizes efficiency in the transonic range at which the aircraft will mostly operate. The cone slopes downward to allow for a straighter bottom profile, facilitating a more consistent airflow into the engine inlet.

The control surfaces consist of two sets of elevons, which are located on the trailing edge of the wing, and rudders located on the back of the vertical fins. The elevons are used to control both roll and pitch, while the rudders control the yaw of the aircraft.

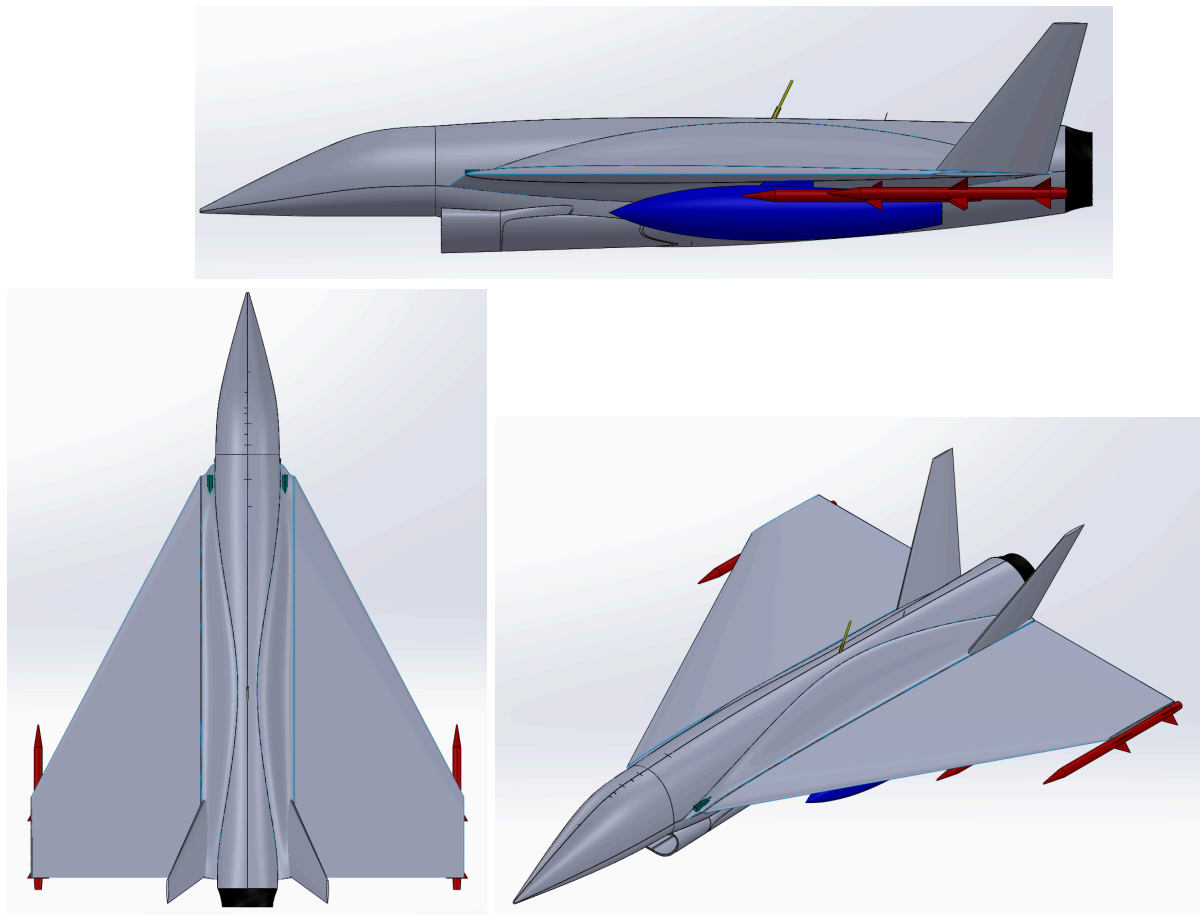


Fig 1.1 Side view, top view, and isometric view of the airframe

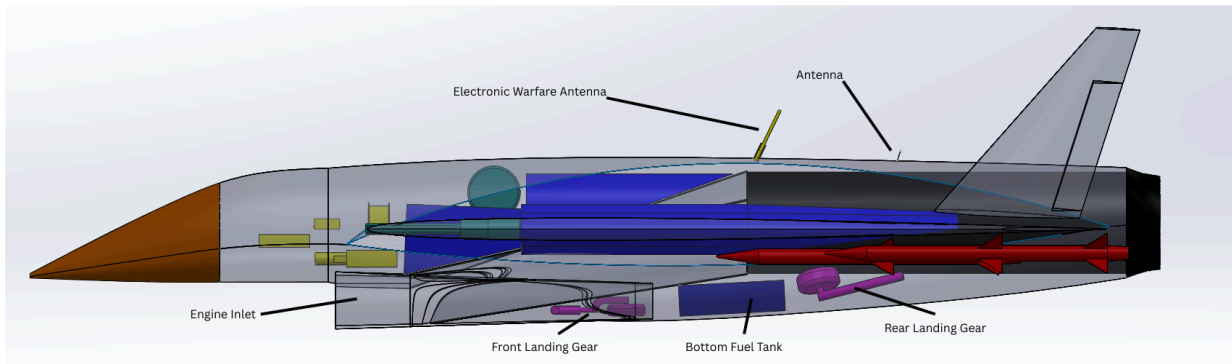
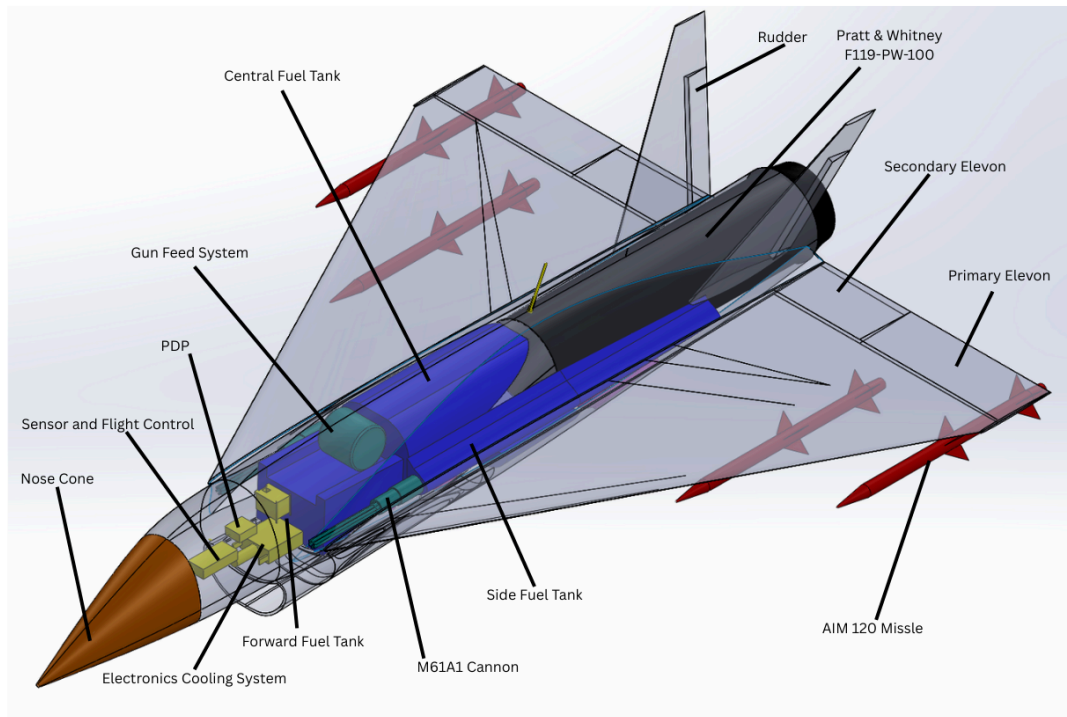


Fig 1.2 Aircraft Internal Components

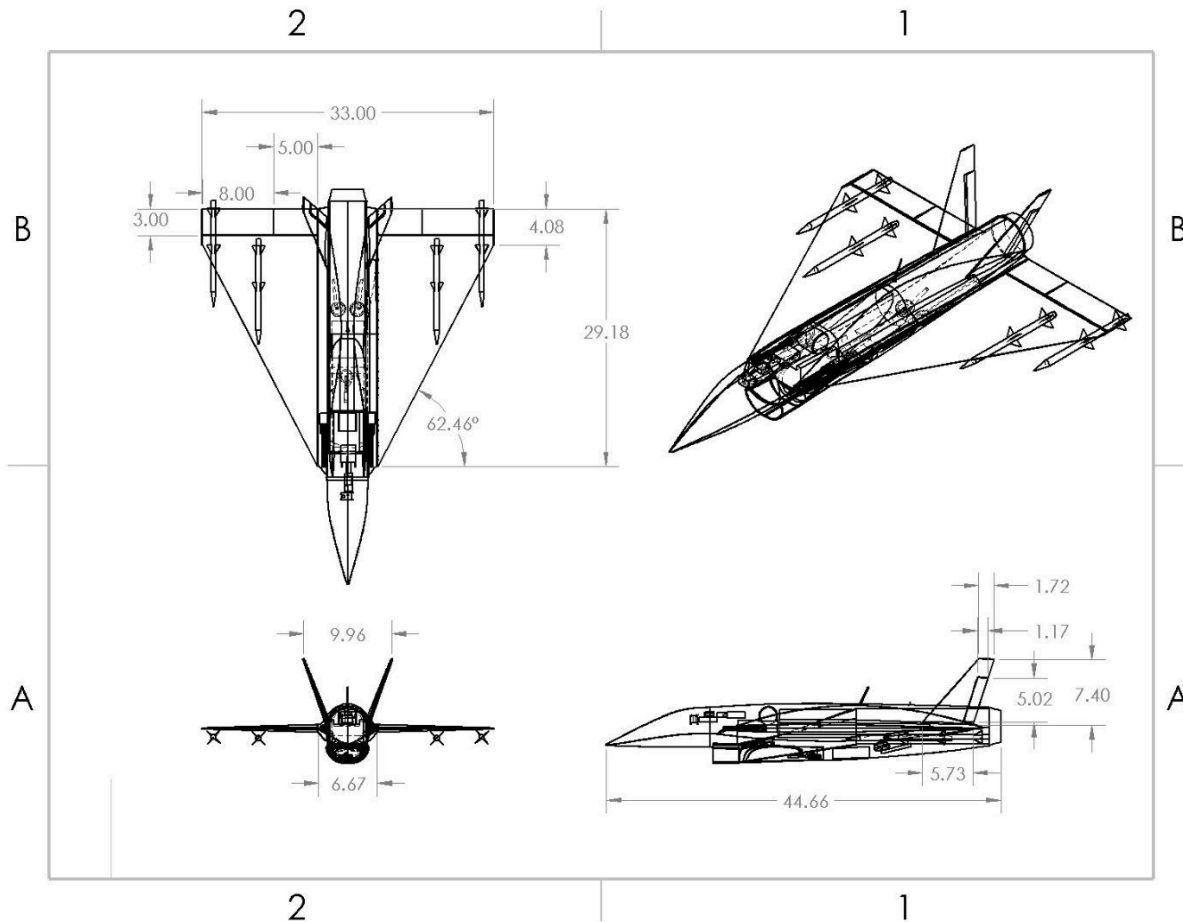


Fig 1.3 Dimensions of the Airframe created using SolidWorks

For takeoff, we designed the aircraft to operate at 60-70% of available engine power with an angle of attack of 8 degrees. Given our max TOGW of 31,000 lbf and an engine thrust of around 24,000 lbf at 70% capacity, our aircraft will be able to achieve enough lift to get airborne with around

In terms of the aircraft's stability, we wanted to achieve a longitudinally unstable aircraft, which goes against conventional aircraft design. While this would normally jeopardize the ability of the aircraft to fly safely, the onboard fly-by-wire system will allow the aircraft to maintain stable flight despite the inherent instability by correcting for the changes through the use of the control surfaces at speeds much faster than could be done by a human. We chose this approach in order to increase the aircraft's maneuverability. With inherent static instability, the aircraft will be drawn toward the direction of the maneuver rather than fighting to return to equilibrium, allowing for quicker maneuvers with less effort compared to a statically stable aircraft. With our current design, the center of lift is calculated to be approximately 25 ft from the nose of the aircraft. Therefore, we designed the center of gravity of the aircraft to be aft of this position, around 30 ft from the tip of the nose. Due to a large amount of estimation in the mass of aircraft

components and a lack of real flight testing, further tests should be performed if this aircraft is built in order to find the optimal static margin and internal weight placement.

## **Structures**

The cost of raw aircraft materials was much less of a limiting factor than initially expected. Because of this, our aircraft can afford the highest quality, most technologically current materials on the market. The airframe is Titanium, used for its incredible mass-to-strength ratio. In the wings and control surfaces, we use additional supports made of honeycomb aluminum to resist shearing forces in high-G circumstances. The shell of the plane is a carbon-epoxy resin compound, the same material used on the F-35, with leading edges made of carbon-bismaleimide. Their properties allow a lightweight plane with enough strength and heat resistance for the maneuvers and speeds produced by our aircraft. Control surface exteriors are made of Kevlar epoxy, and the nose cone is made of S-2 fiberglass, both industry standards. Finally, the landing gear is composed of heavy-strength, corrosion-resistant steel, with a similar makeup to the F-16 landing gear.

FEA simulations were run on airframe components to determine their strength and resistance to force. These simulations were run on the ANSYS platform. Tests were run in an iterative fashion, where weaknesses in the structure were identified, adjusted, and then tested again. Furthermore, internal calculations of volume and spacing were conducted in order to orient the plethora of internal components, including the gun, electronics suite, radars, control surface actuators, landing gear, engine, and fuel. Their support, protection, and functionality within the aircraft were taken into consideration when designing their placements and interactions with the greater aircraft. This includes facets such as windows for bullet casings ejected by the gun, heat/vibration dampeners around the electronics bay, and structural touchpoints connecting the landing gear to the airframe.

Fuel has been a major consideration in this aircraft design. Due to the variable placement of internal fuel tanks and their connection to the engine, multiple nozzle ports for ground fueling will be required to fill all of the internal tanks. Additionally, due to mission constraints provided by AIAA, external tanks will be required to complete long-range loitering missions. These tanks and their interaction with the aircraft will be designed, modeled, and tested by our team.

## **Electronics & Communications**

The HDI-25 aircraft is equipped with a sophisticated mix of government-furnished and externally sourced technologies designed to maximize its survivability and mission success in contested airspace. Core government-furnished systems include an Integrated Communication, Navigation, and Identification (CNI) avionics suite, an Integrated Electronic Warfare (EW) System, and an Infrared Search and Track (IRST) system with laser ranging, which are each playing a critical role in overall operations. These are complemented by externally sourced technologies such as an Active Electronically Scanned Array (AESA) radar, advanced flight control systems, onboard power and cooling units, and a suite of high-resolution sensors and cameras. Together, these components provide the HDI-25 with advanced situational awareness, threat detection, and engagement capabilities. The integration of these systems ensures reliable

performance, efficient information processing, and rapid response times; key to maintaining tactical advantage in high-threat environments.

One of the most critical components of an unmanned defense interceptor is its AESA radar, which enables rapid target detection, tracking, and engagement. Unlike mechanically scanned radars, AESA technology provides faster beam steering, lower probability of interception, and simultaneous tracking of multiple targets. This is especially crucial in air defense scenarios where the interceptor must engage high-speed enemy aircraft and missiles before they reach critical assets. Complementing the radar, theIRST system detects and tracks heat signatures of airborne targets without emitting any signals, making it a redundant yet essential, multifaceted component for stealth operations and passive tracking of enemy aircraft attempting to evade radar detection.

The avionics suite integrates all mission-critical systems, enabling seamless communication between onboard electronics and external networks. This suite processes data from multiple sensors, optimizes aircraft performance, and provides redundancy to mitigate failures. Working in tandem, the CNI system ensures secure and reliable communication, navigation, and target identification. The ability to transmit and receive encrypted data is vital for coordinating with friendly forces and avoiding enemy electronic interference. The EW suite further enhances survivability by detecting and countering incoming threats such as radar-guided missiles and electronic jamming attempts. Through active and passive electronic countermeasures, the EW system can disrupt enemy targeting and protect the aircraft from adversarial threats.

To maintain stability and maneuverability, the flight control system processes real-time inputs from sensors and adjusts control surfaces to ensure precise handling. Given the high-speed engagements typical of interceptor aircraft, these systems must react instantly to changing conditions, particularly in high-G maneuvers. Supporting all of these subsystems, the power and cooling units manage electrical distribution and proper thermal regulation to prevent overheating during flight, considering the potential overheating due to vibrational effects from the weapons feed aft of the electronics bay.

Next, a suite of sensors and cameras plays a crucial role in target identification, surveillance, and navigation. Electro-optical and infrared cameras enhance visibility in all weather conditions, aiding in long-range detection and tracking. These sensors, combined with radar andIRST, provide the interceptor with a comprehensive situational awareness capability, reducing the risk of surprise attacks and ensuring high mission effectiveness.

Finally, a fully integrated health monitoring system is essential to maintain awareness of the damage the aircraft may undergo within high-risk missions. Damage at high Mach numbers and combat with other aircraft, as well as electrical or structural failure within unseen parts of the aircraft is important to pinpoint and fix in order to potentially maximize the overall lifetime of the aircraft.

A fighter jet's Structural Health Monitoring (SHM) system is an advanced network of sensors and diagnostic tools designed to continuously assess the aircraft's structural integrity during operation. These systems use strain gauges, accelerometers, and other sensors to detect stress, fatigue, and potential damage in critical components. Real-time data collection and



processing enable predictive maintenance, reducing hangar time and ensuring mission readiness. By identifying early signs of wear or structural failure, SHM systems enhance safety, extend the aircraft's operational lifespan, and minimize maintenance costs.

The integration of these electrical components is fundamental to the operational success of an unmanned defense interceptor aircraft. AESA radar andIRST systems enable early threat detection, while avionics, CNI, and EW suites ensure secure communication, navigation, and countermeasure deployment. Flight control systems provide stability and maneuverability, whereas power and cooling systems maintain optimal performance under extreme conditions. Advanced sensors and cameras further enhance situational awareness, making the aircraft a highly capable platform for modern air defense missions. As aerial threats continue to evolve, the importance of these technologies will only increase, ensuring that unmanned interceptors remain at the forefront of national security and defense strategies.

## **Cost Allocation**

The Homeland Defense Interceptor Request for Proposal (RFP) lists that entries must achieve a flyaway cost of less than \$25 million in 2024 US dollars. Flyway cost solely measures the cost to manufacture the aircraft. This value does not include flight testing, engineering, or development support. To estimate the per unit flyaway cost, the Development and Production Costs for Aircraft IV (DAPCA IV) cost estimating relationship (CER) was used. The DAPCA IV CER was developed by the RAND in 1987, and it is the model suggested by Daniel Raymer in the 4th version of his book, *Aircraft Design: A Conceptual Approach* (Raymer, 2006).

DAPCA IV relies on three input parameters, maximum velocity, empty weight, and production quantity. A maximum velocity of Mach 1.6 at sea level conditions and a production quantity of 1000 units were used in the calculation. The empty weight of the aircraft was estimated to be roughly 15,800 pounds. To estimate the cost, empty weight was rounded to 17,000 pounds to add an empty weight margin. Using these inputs, the equations provide an estimated value of manufacturing material cost, tooling hours, manufacturing hours, and quality control hours. The tooling, manufacturing, and quality control hours were then multiplied by hourly rates, provided by Raymer in the 2006 edition of his book.

After estimating materials, tooling, manufacturing, and quality control costs, engine cost was estimated using Jan Roskam's book, *Airplane Design Part VIII: Airplane Cost Estimation: Design, Development, Manufacturing and Operation* detailed within Table 1. The formula provides a general price of jet engines producing thrust of 1,000 to 50,000 pounds. (The value produced by the formula provides a price in US dollars in 1989. To estimate the cost increase, the Aerospace Product and Parts Manufacturing, tracked by the US Bureau of Labor Statistics, was used by dividing the December 2024 value, \$279.044, by the January 1989 value, \$110.20, to achieve a multiplier of roughly 2.53.

The last category affecting the flyaway cost is avionics, which is a user input. To budget for avionics, the sum of the above costs was subtracted from the maximum flyaway cost. This

provided the team with a hard cap of \$7.3 million for avionics spending. The full computation is outlined in appendix B.

1: Program and Costs, Amounts Millions.	Aircraft Costs for 1000 Units		
		Total Cost	Per Aircraft
	Tooling	\$ 1,300	\$ 1.3
	Manufacturing	\$ 6,200	\$ 6.2
	Quality Control	\$ 900	\$ 0.9
	Materials Cost	\$ 3,900	\$ 3.9
	Engine	\$ 5,400	\$ 5.4
	Avionics	\$ 7,300	\$ 7.3
	<b>Total Flyaway Cost</b>	<b>\$ 25,000</b>	<b>\$ 25.0</b>
	Table Per Unit in		

## Mass Integration Budget

The design of the Homeland Defense Interceptor 25 (HDI-25) prioritizes a low-cost, high-performance aircraft capable of completing to the highest standards a defensive counter-air, point defense intercept, and intercept/escort mission outlined in the AIAA Undergraduate Design Team Project RFP. A critical aspect of achieving the outlined objectives is maintaining an affordable and lightweight design alternative. The optimization of material selection and the mass budget, to include the integration of all aircraft systems and subsystems is imperative in achieving the flyaway cost constraint of \$25 million per aircraft while still completing all missions at the highest level. The mass budget and integration budget details the mass breakdown, key integration considerations, performance, and mission requirements.

The mass budget of the HDI-25 is driven by the Gross Take-Off Weight (GTOW), which encompasses the empty weight ( $W_e$ ), fuel weight ( $W_f$ ), and payload. The RFP specifies a maneuver weight at 50% internal fuel and while minimizing weight to reduce cost without sacrificing performance such as a maximum Mach number of 1.6 at 35,000 ft and a sustained load factor of 5.0 g's at 0.9 Mach and 15,000 ft. The grouping breakdown for HDI-25 can be seen in table X.

Grouping (HDI-25)	Weight (lbs)	Total Weight (%)
Structure	6500	21.0
Landing Gear	1000	3.2
Propulsion System	5000	16.1
System and Equipment	2310	8.5
Payload (Weapons)	2083	6.7
Electronics and EW	700	2.3
Empty Weight	17593	56.8

Internal Fuel Weight	7800	25.2
External Fuel Weight	5600	18.1
<b>Gross Weight</b>	<b>30993</b>	100

**Table 2:** Mass Budget Breakdown for HDI-25

For calculating the mass grouping for the HDI-25 aircraft we first had to break down each group by subsystem. The empty weight is the mass of the aircraft without accounting for the fuel or the payload weight. The empty weight for the HDI-25 aircraft contains the mass of the structure, landing gear, electronic warfare systems, government furnished equipment, avionics systems, and propulsion systems. The propulsion system decided on is the Pratt and Whitney F119-PW-100, which is used on the F-22 Raptor fighter aircraft. The HDI-25, unlike the F-22, will only utilize one propulsion system instead of two. The fuel weight was calculated by finding the thrust specific fuel ratio for the jet engine used and then from that point there was a statistical estimation done in order to find the amount of fuel that would be consumed for various maneuvers of the aircraft. Including takeoff, dash to max speed, in-air maneuvers, subsonic to supersonic, and landing. The max weight of fuel was taken for the amount needed to complete the defense counter air patrol mission because that was noticed to be the mission that required the most fuel. The payload mass was calculated with the mass of weapon systems that would be used multiplied by the number of each. For the HDI-25 there will be 4 AIM - 120 AMRAAM missiles and 1 M61A1 20 mm Cannon with 500 rounds of ammunition.

The HDI's mass budget and systems integration achieve a lightweight, cost-effective design that is meticulously tailored to the homeland defense requirements given by the AIAA. With a gross takeoff weight of 30993 lbs, the aircraft integrates a lightweight structure design, a high-performance engine, and compact weapons systems to meet mission demands without sacrificing the strict budget constraints outlined in the RFP, detailed within Table 2.

## Propulsion

The HDI-25 propulsion system consists of a government-furnished engine with a fully-designed intake and fuel line system. The beginning of the process for choosing a propulsion system required the estimation of a gross takeoff weight from statistical analysis of prior designed planes that completed similar missions. From this analysis, the takeoff-to-weight ratio and the wing loading could be calculated using further analysis. These two analyses were completed with the use of Raymer's book, *Aircraft Design: A Conceptual Approach*. From the takeoff-to-thrust ratio and the gross takeoff weight, the thrust required for the jet to takeoff in the required amount of runway could be calculated. During the calculations of thrust-to-weight ratios, the data from an already existing engine was used as a baseline. This allows the engine which is to be implemented to be chosen from a model which adjusts the engine weight, length, diameter, and thrust to match the requirements. This led to the chosen engine model, F119-PW-100. This engine includes a suite which has an Auxiliary Power Unit (APU) already installed. Therefore, no calculations were needed to add an additional APU for the case where the engine power is not sufficient to maintain flight.

Following the choosing of an engine, the air intake required to allow the jet to fly at mach 1.6 was calculated. The air intake capture area was calculated using the bypass-ratio and the air-mass flow rate for the chosen engine. From the known area, it could be determined the exact size of the intake given an analysis of previous jet engine intakes and the one which best fit the needs for this jet. The intake therefore was placed under the nose of the airplane with a diverter to prevent boundary layer issues with a kidney bean shape.

A key propulsion design requirement is specific excess power, with multiple lines in the RFP being dedicated to outlining specific excess power requirements. Specific excess power is extremely important to fighter jets because it is one way to quantify maneuverability, and having a higher specific excess power than the enemy is an advantage. In the RFP, Attachment 4 describes the required specific excess power at different loading situations, altitudes, mach numbers, and thrust conditions. Additionally, in section 4.0: Measures of Merit, criteria 4.5.2 and 4.5.3 request specific excess power envelopes at 1g and 5g loading conditions at maximum thrust, shown below in Equation 1. To be able to make a specific excess power envelope, we had to calculate thrust and drag over our entire flight envelope. This is a notoriously difficult task since this requires the estimation of transonic drag,

$$P_s = \frac{V(T \cos(\alpha) - D)}{W}$$

**Equation 1:** Specific Excess Power Equation: speed, thrust, weight, and drag denoted as V, T, W, D, and  $\alpha$ , respectively.

and the estimation of nozzle inlet dynamics. Transonic drag was calculated by interpolating between the last subsonic point and the first supersonic point, both estimated with equations from Raymer. The change in thrust with altitude was done with a step by step thermodynamic analysis of the turbofan engine cycle, and iterated over with matlab. The code for drag is contained in Appendix E, thrust in Appendix D, and specific excess power in Appendix F. The plots of specific excess power, both the two necessary and a couple more that were useful in various design stages are contained in Appendix G. These plots prove that our plane is generally pretty powerful, but has some shortcomings at sea level flight conditions. This could be a result of inaccuracy in our analysis since our calculations of transonic drag and inlet dynamics were rudimentary, but also could be due to our design engine mass flow rate being too low or our airplane design creating too much drag.

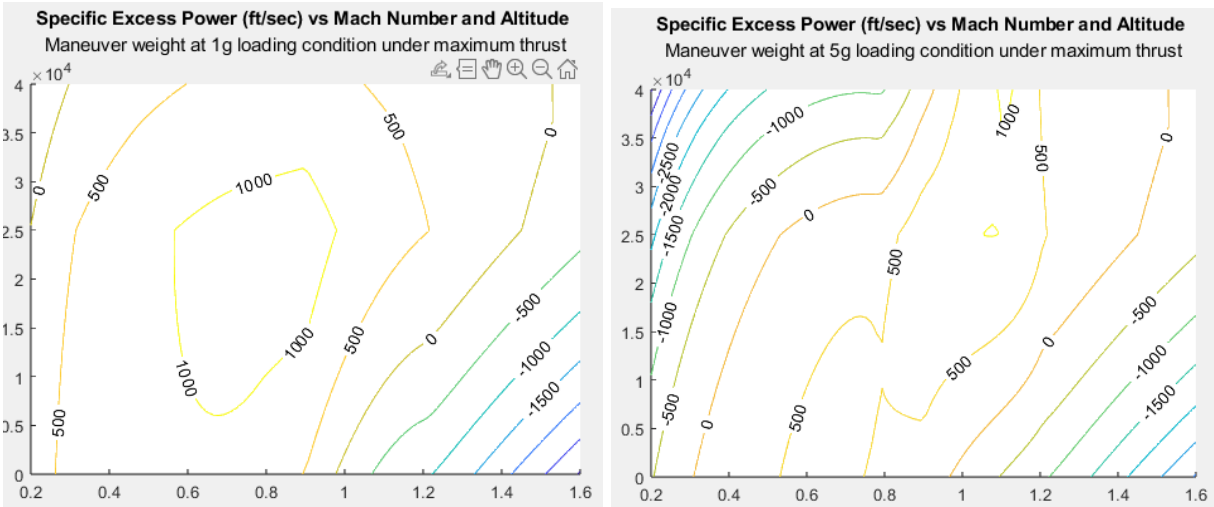


Figure 2: AIAA Required Specific Excess Power Plots: Maximum thrust, 1g and 5g loading

## Additional Considerations

The development of a remotely piloted homeland defense interceptor aircraft presents several factors of risk with each portion of the aircraft (Appendix C). Furthermore, when creating an aircraft such as the project details, there are many ethical considerations, particularly regarding human oversight in military engagements. While the aircraft itself is controlled by a human operator in a ground station, the integration of autonomous aiming and weapons control raises concerns about accountability and decision-making in combat situations. According to Lieutenant Colonel Thomas A. Rudy of the United States Air Force, ensuring that the targeting systems “continue to require the ability to strike targets with increased accuracy” and ensuring that “accurate and timely intelligence support” is at the heart of weapons operations, the system can be deemed more ethical than that of which it does not (Rudy, 2013). In the theoretical design of this aircraft, we are assuming the accuracy of the aiming and firing systems are accurate enough to never misfire, falsely aim at unintended targets; completing missions with greatest accuracy. Rudy also states that “the term unmanned should not be used whenever a weapon system is actually controlled or piloted by people.” In the case of this “*Unmanned Homeland Defense Interceptor*” we assume the weapons system is autonomous and there is no human interaction with the weapons controls to target or attack, further adhering to the rules Rudy states in his argument. Additionally, the rapid-response nature of such aircraft may lower the threshold for engagement, increasing the potential for unintended escalations in conflict. Ethical concerns also extend to cybersecurity risks, as remotely piloted aircraft are vulnerable to hacking or electronic warfare, potentially allowing adversaries to disrupt or even take control of the system.

From an environmental perspective, the aircraft’s fuel consumption, material selection, and long-term sustainability must be carefully considered. Military aircraft are traditionally high-performance machines that consume significant amounts of fuel, contributing to high carbon emissions, contributing to the degradation of the Earth’s atmosphere. While efficiency improvements in engine design and sustainable aviation fuels may help mitigate this impact, the

interceptor's high-speed, high-maneuverability requirements make full electrification or alternative propulsion challenging. Additionally, the use of composite materials and lightweight alloys can reduce overall fuel consumption while maintaining structural integrity. Another environmental concern is the disposal and lifecycle management of these aircraft—ensuring that decommissioned units are properly recycled or repurposed rather than contributing to hazardous waste.

From a professional standpoint, engineers and defense contractors must ensure the aircraft adheres to strict safety, regulatory, and operational standards to maintain reliability in national defense. The integration of advanced avionics, secure communications, and semi-autonomous targeting systems requires collaboration between aerospace engineers, cybersecurity experts, and military strategists to ensure a balance between performance, cost, and mission effectiveness. Additionally, geopolitical and export control considerations must be addressed to prevent unauthorized use or proliferation of the technology. Transparency in design, compliance with international arms agreements, and adherence to ethical engineering practices will be critical in ensuring that the aircraft serves as a responsible and effective national defense asset.

## **Conclusion**

The HDI-25 Homeland Defense Interceptor is a cost-effective, high-performance aircraft designed to secure national airspace against emerging threats. Its airframe strategically balances durability, maneuverability, and cost-efficiency through optimized material selection and structural design. By integrating a lightweight yet robust airframe, the HDI-25 achieves a Gross Takeoff Weight (GTOW) of 24,028 lbs while maintaining structural integrity under high-speed and high-G maneuvers. The use of proven aerodynamic configurations and carefully selected control surfaces ensures the aircraft meets its mission requirements for point defense, escort, and counter-air intercept roles.

A sophisticated suite of avionics, sensors, and radar systems enhances situational awareness and survivability, enabling effective threat detection and engagement. The integration of an Active Electronically Scanned Array (AESA) radar and Infrared Search and Track (IRST) system ensures early threat detection and target tracking, while a secure Communication, Navigation, and Identification (CNI) system facilitates encrypted data exchange and coordination with friendly forces. The Electronic Warfare (EW) suite provides both active and passive countermeasures to protect against electronic threats, and a Structural Health Monitoring (SHM) system continuously assesses airframe integrity to minimize maintenance costs and extend operational lifespan.

The propulsion system, featuring the F119-PW-100 engine and a tailored intake design, provides the thrust and fuel efficiency necessary for sustained mission success. The intake was designed using historical data and computational analysis to ensure optimal air capture while minimizing boundary layer effects. MATLAB simulations validated the aircraft's ability to maintain a Mach 1.6 cruise speed at 35,000 feet, sustain 5.0g maneuvers at Mach 0.9 and 15,000 feet, and complete the most fuel-demanding mission profile, ensuring that onboard fuel capacity is sufficient for operational needs.

By utilizing industry-standard cost estimation models and meticulous resource allocation, the HDI-25 maintains a flyaway cost under \$25 million per unit. The Development and Production Costs for Aircraft IV (DAPCA IV) model was used to estimate material, manufacturing, tooling, and quality control expenses, while Jan Roskam’s cost estimation method was applied to engine pricing. The avionics budget was constrained based on remaining funds after core manufacturing and propulsion costs, ensuring that critical systems could be integrated without exceeding the cost ceiling.

The HDI-25’s carefully managed mass budget and systems integration ensure an optimal balance between performance, cost, and mission capability. The structure, propulsion, and onboard systems were optimized to meet performance requirements while adhering to strict weight constraints, allowing for a capable weapons loadout of four AIM-120 AMRAAM missiles and an M61A1 20mm cannon with 500 rounds. The integration of lightweight materials and efficient systems contributes to the interceptor’s ability to achieve rapid response times and extended operational life.

Through rigorous design, integration, and verification, the HDI-25 delivers a scalable, long-term solution for homeland defense. By overcoming the challenges of cost constraints, weight optimization, and mission effectiveness, the HDI-25 ensures the United States remains prepared to counter future aerial threats with a robust and efficient defense system.

## References

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- Rudy, T. A. (2013). The Morality of Employing Remotely Piloted Weapon Systems in Combat. <https://doi.org/10.21236/ada590671>

## Appendices

### Appendix A: Team Structure and Personnel

Team Management Roles	Members
Team Lead	Nora Wilkerson
Technical Lead	June Wiles
Communications Lead	Savannah Hafer

Subsystem Leads and Teams	Members
Aircraft Structures	<b>Agha Mohammad Ali</b> , Matthew Shin
Aircraft Propulsion	<b>Reid Smith</b> , William Couch
Aerobody Design and Modeling	<b>Matthew Shin</b> , Agha Mohammad Ali
Electronics and Communications	<b>Eric Fryer</b> , Nora Wilkerson
System Integration and Mass Allowance	<b>Evan Hahn</b> , June Wiles, Savannah Hafer
Cost and	<b>William Couch</b> , Savanna Hafer, Nora Wilkerson

## Appendix B: Full Budget

Inputs	Value
Empty Weight (lbs)	17000
Maximum Velocity (knots)	1060
Production Quantity	1000

Table 3: Input values from RFP and design specifications.

	Total (hours)	Per Aircraft (hours)
Engineering Hours	14700040	14700
Tooling Hours	9101197	9101
Manufacturing Hours	52927776	52928
Quality Control Hours	7039394	7039

Table 4: Man-hour estimates calculated from the above three input variables.

	Estimate Today (2024 Edition)
Engineering	115.00



Tooling	118.00
Quality Control	108.00
Manufacturing	98.00

Table 5: Above are the recommended hourly rates from Raymer in the 2024 edition of *Aircraft Design: A Conceptual Approach*.

Roskam VIII Engine Cost	
1989	Today
2135677	5407874

Table 6: Cost of each F119 engine in dollars. Jan Roakam's book, *Airplane Design Part VIII: Airplane Cost Estimation: Design, Development, Manufacturing and Operation*, contains an equation to estimate the cost of a turbojet engine in 1989 dollars. The Aerospace Product and Parts Manufacturing Producer Price Index was used to estimate the cost of the engine in 2024 dollars.

Aircraft Costs for 1000 Units		
	Total Cost	Per Aircraft
Tooling	\$ 1,300,000,000	\$ 1,300,000
Manufacturing	\$ 6,200,000,000	\$ 6,200,000
Quality Control	\$ 900,000,000	\$ 900,000
Materials Cost	\$ 3,900,000,000	\$ 3,900,000
Engine	\$ 5,400,000,000	\$ 5,400,000
Avionics	\$ 7,300,000,000	\$ 7,300,000
<b>Total Flyaway Cost</b>	<b>\$ 25,000,000,000</b>	<b>\$ 25,000,000</b>

Table 7: The above equations estimate tooling, manufacturing quality control, materials, and engine costs. All of the calculated values, except engine costs, were further multiplied by 1.2 as a materials fudge factor, as recommended by Raymer. After summing all of the calculated values, there is \$7.3 million per unit is left as a hard cap for the avionic budget. This means the plane should be well under budget.

## Appendix C: Risk Management

Risk	Subteam	Consequence	Mitigation
Uninnovative	All	Project cancellation	Careful analysis of component history
Mission Failure	All	Enemy will continue to target	Full mission simulations

Weapons External Misfire	Electronics	Mission failure, potential damage to property/life	Reliable, multistep firing system, resistant aerobody
Communication Loss	Electronics + Comms	Aircraft damage & crash, mission failure, enemy offense continued, loss of control to weapons	Strong, reliable communication system
Control Failure	Electronics+Comms	Aircraft crash, mission failure, enemy offense continued, loss of controls to weapons and aircraft	Strong, reliable piloting system with several communication lines
Weapons Internal Misfire	Electronics + Comms	Aircraft damage, mission failure, enemy offense continued	Reliable, multistep firing system and design resistant inner compartment
Hacking	Electronics + Comms	Turn weapons into own people or crash	Multistep, multistage, complex system that requires physical presence within piloting station to avoid external hacking
Material Acquisition	Structures + Materials	cost overrun, schedule delay, project cancellation	Analyze supply and demand within the context of the economy
Landing Gear Failure	Structures + Materials	Rough landing, inability to land on specific terrain	Durable, tested landing gear and simulate instances of failure to mitigate destruction in the event of failure
Material Damage	Structures + Materials	Materials not conducive to all weather qualifications, rust/corrosion or high speeds resulting in mission failure, project cancellation, schedule delay and cost overrun	Strong, applicable material that is easily replicated and repaired
Thermal Stress	Structures + Materials	Materials experiencing stress due to air friction, sufficient thermal protection necessary within the materials	Analyze and simulate different weather conditions and use heat resistance materials
Impact Resistance	Structures + Materials	Impact with birds, drones and other could cause crash and mission failure	Simulate unavoidable circumstances (i.e. bird collision) and analyze impact resistant materials for outer body
Cost Overrun	Cost Efficiency	Schedule delays, project cancellation	Analyze budget with individual components within the acquisition of necessary items
Engine Failure	Propulsion	Total engine failure would result in the aircraft crash landing	Reliable, resistant engine and analyze the limitations of the component
Thermal Failure	Propulsion	Due to high speed airflows, thermal failure could be mitigated by engine	Analyze limitations of the aircraft in order to stay within

		design and materials	the engine's desired thermal bracket
Compressor Stall/Surge	Propulsion	Disruptions in airflow could cause stall/loss of thrust therefore incomplete mission and potential crash	Analyze limitations of component and create contingency in the event of unavoidable stall
Fuel Supply	Propulsion	Not enough fuel could result in mission failure	Analyze fuel amount necessary for mission and build tank around engine compatibility and weight distribution
Fuel Leak	Propulsion	Not enough fuel , could result in mission failure or emergency landing	Strong fuel compartment separated from possible combustion risks
Aircraft Weight too high	Mass Budget	Engine stress, missions incomplete, unstable, requirements not met	Find alternative components that decrease gross weight
Aircraft Weight too low	Mass Budget	Engine stress, unstable, mission requirements not met	Find alternative components that increase gross weight
Weight distribution Issues	Mass Budget	Unstable, engine stress, post weapon fire stability issues	Weight calculations & simulations in order for correct payload placement
Weight after weapon launch	Mass Budget	Post launch would allow for instability to increase as standard weight is not distributed	Simulate weight with all weapons, some launched and none to accommodate
Propellant Weight	Mass Budget	Mass loss too quick, unstable and could cause for emergency landing and mission failure	Distribute the propellant evenly to allow for not drastic changes in weight that affects mission/landing
Deficient Aerodynamic Aerobody design	Aerobody	Increased drag impacts engine stress, mission requirements not met,	Create streamline, aerodynamic aero body that mitigates the impact of drag
Stability Control	Aerobody	If not aerodynamically balanced, loss of control can cause failure in mission	Simulate mission circumstances that would cause instability and design contingencies
Low Radar Design	Aerobody	Make it relatively undetectable to enemy radar	Analyze the components that could be detected by enemy radars from radio to physical body
Incorporating Weapons into design	Aerobody	If weapons launching cause for aerodynamic issues the missions could fail or the aircraft could crash	Analyze the internal or external positions in contribution to the aerodynamics of the aerobody
Surface quality	Aerobody	Drag increases engine stress and instability	Mitigate rivets and ridges to decrease drag

## Appendix D: Matlab code for thrust calculations

```
function [m_dota, TSFC, Thrust, TSFCAB, ThrustAB] = afterburningTF(M, z, A_in, T_04MAX, P_rc, B)
% M, Z, radius, T04_MAX, Compressor Pressure Ratio, Bypass Ratio
% Engine Simulation
% Flight Conditions

% Altitude and air properties
[Ta, ~, Pa, rhoa] = atmosisa(z);
R = 287; %R/MM

% Speed
g = 1.4;
u = M*sqrt(g*R*Ta);
% m_dota = rhoa*A_in*u;
T_total = Ta*(1+0.5*(g-1)*M^2);
P_total = Pa*(T_total/Ta)^(g/(g-1));
% m_dota = Pa*A_in*M*sqrt(g/T_total*9.807/R*(P_total/Pa)^((g-1)/g));
design_mach = 0.9;
design_z = 25000/3.281;
ideal_m_dota = rhoa*A_in*u;
design_m_dota = 150;
```

```

if(M<design_mach && z < design_z)
    m_dota = 150;
elseif(z < design_z)
    A_adjusted = A_in*1/(2*M/design_mach-1);
    m_dota = 150*1/(2*M/design_mach-1);
elseif(M < design_mach)
    [~, ~, ~, ideal_rho] = atmosisa(design_z);
    m_dota = design_m_dota*rhoa/ideal_rho;
else
    [~, ~, ~, ideal_rho] = atmosisa(design_z);
    m_dota = 150*1/(2*M/design_mach-1)*rhoa/ideal_rho;
end
% Inlet
T_02 = Ta*(1 + (g-1)/2*(M^2));
if M>1
    n_d = 0.9*(1-.075*(M - 1)^1.35);
else
    n_d = .9;
end
P_02 = Pa*(1 + n_d*(T_02/Ta-1))^(g/(g-1));

% Fan
P_rf = 1.5;
P_08 = P_02 * P_rf;
n_f = .95;
T_08 = T_02 * (1 + (1/n_f)*(P_rf^((g-1)/g)-1));
u_ef = sqrt(2*n_f*g/(g-1)*R*T_08*(1-(Pa/P_08)^((g-1)/g)));

% Compressor
%Input: P_rc
P_03 = P_rc*P_02;
n_c = .95;
T_03 = T_02*(1+(1/n_c)*(P_rc^((g-1)/g)-1));

% Burner
%Input: T_04 (turbine inlet temp)
T_04 = T_04MAX; %K
QR = 42000000; %J/kg
C_p = 1005; %J/kg

```

```

f = (T_04/T_03-1)/(QR/(C_p*T_03)-T_04/T_03);
P_04 = .9*P_03;

% Turbine
n_t = .85;
T_05 = T_04 - C_p/(n_c*n_t*C_p)*(T_03-T_02)-B*(T_08-T_02);
P_05 = P_04*(1-1/n_t*(1-T_05/T_04))^(g/(g-1));

% No AB
T_06 = T_05;
P_06 = P_05;

% Afterburner
Tmax_AB = 2000;
T_06AB = Tmax_AB;
P_06AB = P_05;
fAB = (T_06AB/T_05-1)/(QR/(C_p*T_05)-T_06AB/T_05);

% Nozzle
n_n = .9;
u_en = sqrt(2*n_n*g/(g-1)*R*T_06*(1-(Pa/P_06)^((g-1)/g)));
u_enAB = sqrt(2*n_n*g/(g-1)*R*T_06AB*(1-(Pa/P_06AB)^((g-1)/g)));

%Thrust
SpT = ((1+f)*u_en+B*u_ef-(1+B)*u); %N/kg
Thrust = SpT*m_dota;
%Thrust = m_dota*((1+f)*u_en+B*u_ef-(1+B)*u);
SpTAB = ((1+f)*u_enAB+B*u_ef-(1+B)*u);
TSFC = f/SpT;
ThrustAB = SpTAB*m_dota;
TSFCAB = (fAB+f)/SpTAB;

end

```

## Appendix E: Matlab Code for Drag Calculations

```

1  function [CD, D, CD0] = dragCalc(alt, M, S, n, W, AR)
2
3  g = 1.4;
4  R = 287;
5  planeff = 0.75;
6  [T, a, P, rho] = atmosisa(alt/3.281);
7  u = M*sqrt(g*R*T)*3.281; %ft/sec
8  q = 0.5*rho/515.4*u^2; %slugs/ft*s
9  K = 1/(pi*AR*planeff);
10 k_rough = 3.33*10^(-5);
11 sections = ["Fuselage", "Wing", "Vertical Tail"];
12 l = [40 16 27.9077/12];
13 S_wet = [(40*10*pi+2*5^2*pi) S^2 10];
14 total_Swet = S_wet(1)+S_wet(2)+S_wet(3);
15 Amax = 29;
16 sweep = 60;
17 Cfc = 0;
18 Cf_total = 0;
19 if M<=0.79
20     CD0 = .0035*total_Swet/S;
21     CL = W/(q*S);
22     D = (q*S*CD0+K/q*n^2*W^2/S)/sqrt(1-M^2);
23     CD = D/q/S;
24 elseif M >= 1.21
25     for i = 1:length(sections)
26         R = 44.62*(l(i)/k_rough)^(1.053)*M^1.16;
27         Cfc = .45/(log(R)/log(10)*(1+.144*M^2)^.65);
28         Cf_total = Cf_total+Cfc*S_wet(i);
29     end
30     CD0 = 1.05*(Cf_total/S + 2.5*(1-.386*(M-1.2)^.57)*(1-pi*(sweep^.77)/100)*9*pi/2*(Amax/l(1)));
31     CD0 = CD0/S;
32     %dietrich kuchermann
33     D = 1.5*(CD0*q*S+M/(4*(M+3)*W*n));
34     CD = D/q/S;
35 else
36     CD0 = 0;
37     [maxCD, maxdrag, maxCD0] = dragCalc(alt, 1.21, S, n, W, AR);
38     [minCD, mindrag, minCD0] = dragCalc(alt, 0.79, S, n, W, AR);
39
40     x = [.79 1 1.21];
41     y = [minCD maxCD*1.3 maxCD];
42     p = polyfit(x, y, 2);
43     CD = p(1)*M^2+p(2)*M+p(3);
44     D = CD*q*S;
45
46 end
47 %Cd = Cd0 + KCL^2 if M<0.4

```

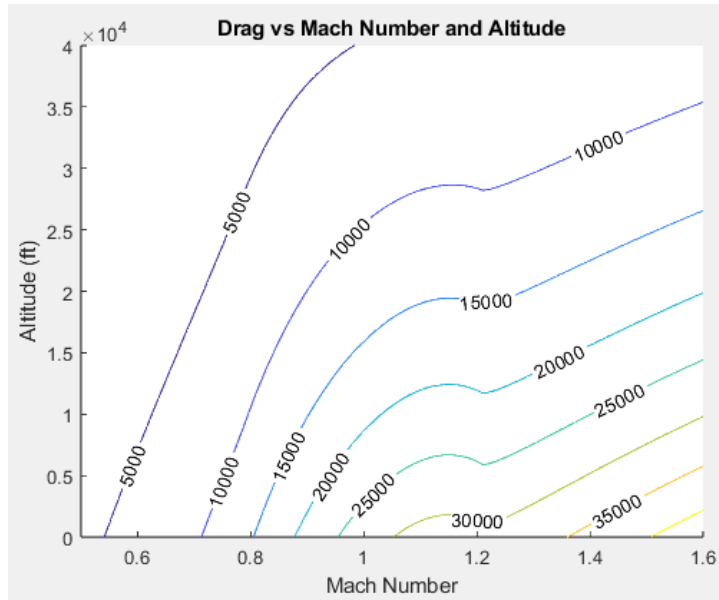


Figure 3: Results of the drag analysis including subsonic range ( $M < 0.8$ ) transonic range ( $0.8 < M < 1.2$ ) and supersonic range ( $M > 1.2$ )



## Appendix F: Matlab Code for Specific Excess Power Calculations

```

1  %excess specific power
2  clear all
3  % (V*(T*cos(alpha) - D)/W
4
5  M = linspace(0.2, 1.6, 100); % mach
6  S = 720; %ft^2
7  altitude = linspace(0, 40000, 200);
8  R = 1716;
9  gamma = 1.4;
10 V = zeros(length(M), length(altitude));
11
12 %Takeoff Weight
13 W_TO = 24028;
14 W_f = 7810;
15 %combat weight
16 W = W_TO-.5*W_f;
17
18 % Cl/alpha calcs
19 a0 = 2.578; %rad
20 lambda = 60*pi/180;
21 AR = 1.23;
22 acomp = a0*cos(lambda) ./ (sqrt(1-M.^2*cos(lambda)^2*(a0*cos(lambda)/(pi*AR))^2+(a0*cos(lambda)/(pi*AR)))); %scalar for now
23
24 for i = 1:length(altitude)
25     for j = 1:length(M)
26         [~, ~, T(i, j), ~, TAB(i, j)] = afterburningTF(M(j), altitude(i)/3.281, .51, 1922, 26, 0.3);
27         V(i, j) = M(j)*sqrt(gamma*R*calcTempRankine(altitude(i))); %ft/sec
28         Cl_min(i, j) = W./(0.5*calcRhoSlugs(altitude(i))*S.*V(i, j).^2);
29         alpha_min(i, j) = 180/pi*Cl_min(i, j)/acomp(j);
30         [q_lg(i, j), D_lg(i, j)] = dragCalc(altitude(i), M(j), S, 1, W, AR);
31         [q_lg_TO(i, j), D_lg_TO(i, j)] = dragCalc(altitude(i), M(j), S, 1, W_TO, AR);
32         [q_5g(i, j), D_5g(i, j)] = dragCalc(altitude(i), M(j), S, 5, W, AR);
33         Spex_lg_Mil(i, j) = V(i, j)*(T(i, j)/4.448*cosd(alpha_min(i, j))-D_lg(i, j))/W;
34         Spex_lg_Max(i, j) = V(i, j)*(TAB(i, j)/4.448*cosd(alpha_min(i, j))-D_lg(i, j))/W;
35         Spex_5g_Max(i, j) = V(i, j)*(TAB(i, j)/4.448*cosd(alpha_min(i, j))-D_5g(i, j))/W;
36         Spex_lg_Max_TO(i, j) = V(i, j)*(TAB(i, j)/4.448*cosd(alpha_min(i, j))-D_lg_TO(i, j))/W_TO;
37     end
38 end
39
40 figure("Name", "Drag")
41 hold on
42 [C, h] = contour(M, altitude, D_lg);
43 clabel(C, h)
44 hold off
45 figure("Name", "lg Military Maneuver")
46
47 hold on
48 title("Specific Excess Power (ft/sec) vs Mach Number and Altitude ", sprintf("Maneuver weight at lg loading condition under military thrust\n"))
49 %surf(M, altitude, Spex, 'EdgeColor','none')
50 [C, h] = contour(M, altitude, Spex_lg_Mil);
51 clabel(C, h)
52 hold off
53 figure("Name", "lg Maximum Maneuver")
54 hold on
55 title("Specific Excess Power (ft/sec) vs Mach Number and Altitude ", sprintf("Maneuver weight at lg loading condition under maximum thrust\n"))
56 %surf(M, altitude, Spex, 'EdgeColor','none')
57 [C, h] = contour(M, altitude, Spex_lg_Max);
58 clabel(C, h)
59 hold off
60 figure("Name", "5g Maximum Maneuver")
61 hold on
62 title("Specific Excess Power (ft/sec) vs Mach Number and Altitude ", sprintf("Maneuver weight at 5g loading condition under maximum thrust\n"))
63 %surf(M, altitude, Spex, 'EdgeColor','none')
64 [C, h] = contour(M, altitude, Spex_5g_Max);
65 clabel(C, h)
66 hold off
67 figure("Name", "lg Maximum Takeoff")
68 hold on
69 title("Specific Excess Power (ft/sec) vs Mach Number and Altitude ", sprintf("Takeoff weight at lg loading condition under maximum thrust\n"))
70 %surf(M, altitude, Spex, 'EdgeColor','none')
71 [C, h] = contour(M, altitude, Spex_lg_Max_TO);
72 clabel(C, h)
73 hold off

```

## Appendix G: Specific Excess Power Plots

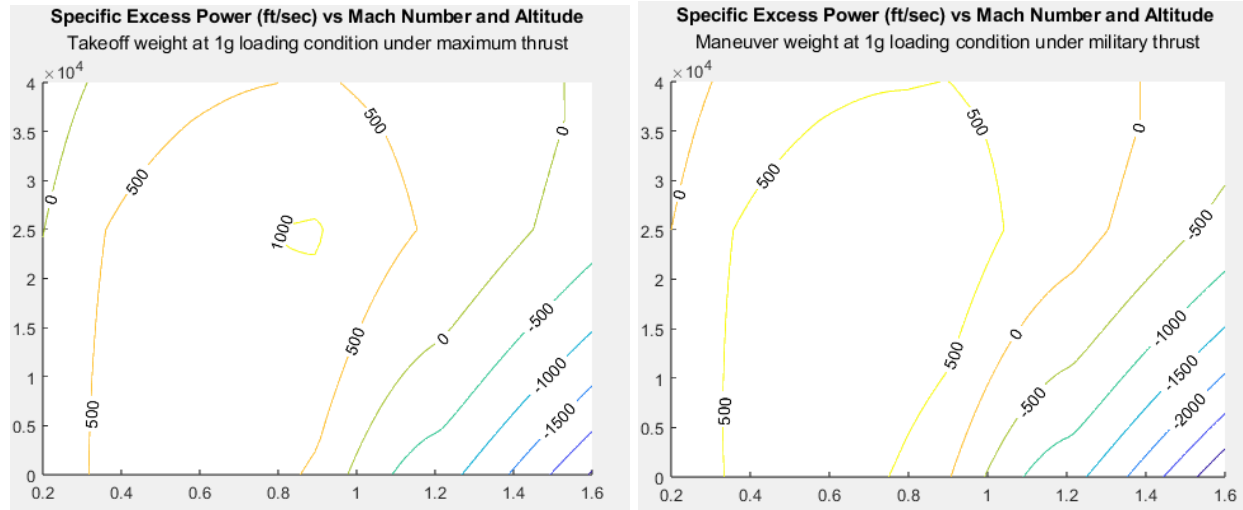


Figure 2: Other specific excess power plots for calculating takeoff, climb, and optimal loiter/cruise conditions

## Appendix H: Mass Budget

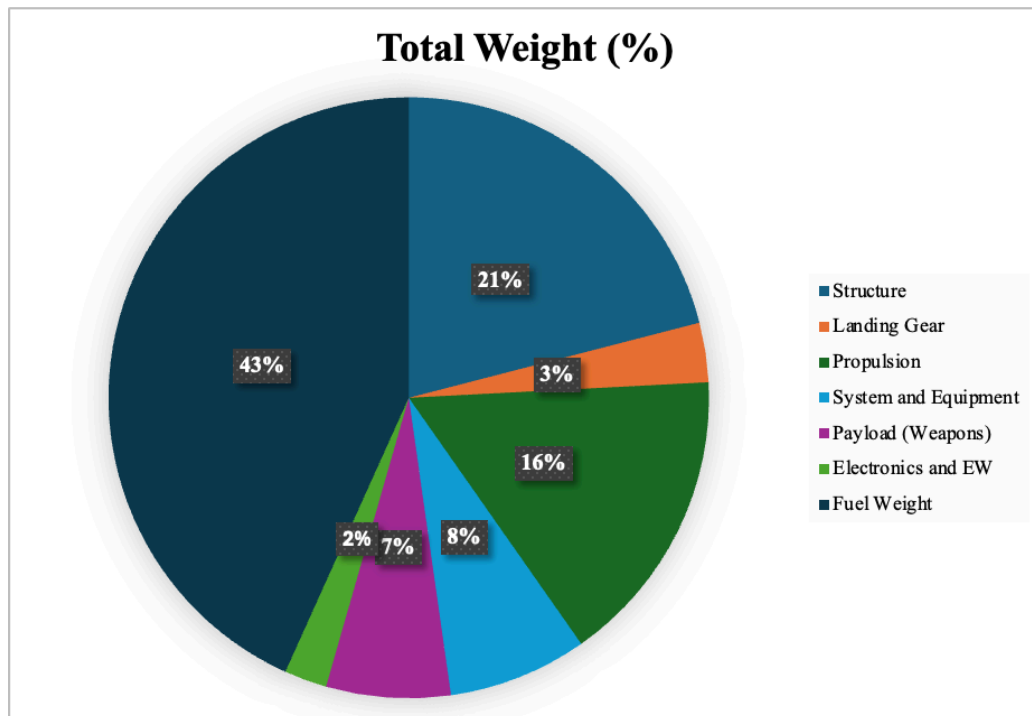


Figure 4: Total Mass Breakdown Percentages