Prospectus

Austere Field Light Attack Aircraft
(Technical Topic)

Military Innovation
(STS Topic)

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.

Signed: Robbie Sorrentino
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Introduction

The American Institute of Aeronautics and Astronautics (AIAA) sponsors design competitions each year. My team has been tasked with determining a solution based on a Request for Proposal (RFP) of a light attack aircraft. Our work will consist of testing the hypothetical solution, technically evaluating its effectiveness, and conducting a cost analysis. Our capstone will culminate in preparing a final report that will be submitted in response to the RFP to be judged by experts in the field. Affordability is mentioned as a primary design constraint in the RFP. Thus, I have decided to bridge research on the technologies used to build light attack aircraft to the justifications for these decisions as it relates to cost in the U.S. military landscape. Current light attack aircraft like the F-22 Raptor and F-35 Joint Strike Fighter are incredible technological achievements but are very expensive to build, operate, and maintain. What are the advantages and disadvantages of using a more affordable solution like the AT-6 Wolverine or A-29 Super Tucano? Which aircraft have the Department of Defense decided on providing for the United States Air Force and why? My Technical thesis will explore these trade studies and present an overview of the light attack class of aircraft. My STS thesis will seek to explain how the Department of Defense has approached and justified spending on the F-35 program. This Joint Strike Fighter development and acquisition program has often seen much restructuring due to affordability and readiness issues. Various models of military innovation may help to explain the power structure and decision-making process that resulted in some of these issues.

Technical Topic

The objective of the project is to design an affordable light attack aircraft that can operate from short, austere fields near the front lines to provide close air support to ground forces at short notice and complete some missions currently only feasible with attack helicopters. An austere field is defined by the Department of Defense as an unsophisticated airfield, usually with a short runway, that is limited in one or a combination of the following: taxiway systems, ramp space, security, materials handling equipment, aircraft servicing, maintenance, navigation aids, weather observing sensors, and communications (JP 3-17 US DoD, 2019). Under the guidance of Dr. Jesse Quinlan, a senior aerospace engineer in the Aeronautics Systems Analysis Branch at NASA Langley Research Center and Guest Lecturer at the University of Virginia, I, Riley Assaid, Alfredo Basile, Ben Hamer, Ryan Hughes, Andrew Kraemer, and Caleb Mallicoat will design an austere field light attack aircraft. The requirements the proposed aircraft must meet are outlined in Figure 1.

Figure 1. Austere Field Light Attack Aircraft Requirements (AIAA, 2020).

Requirements: [R] = Mandatory Requirement [O] = Objective or Goal

General Requirements

The requirements and objectives below are applicable to both aircraft within the family.

- [R] Austere Field Performance: Takeoff and landing over a 50 ft obstacle in ≤ 4,000 ft when operating from austere fields at density altitude up to 6,000 ft with semi-prepared runways such as grass or dirt surfaces with California Bearing Ratio of 5
- [O] Survivability: Consideration for survivability, such as armor for the cockpit and engine, reduced infrared and visual signatures, and countermeasures (chaff, flares, etc.).
- [R] Payload: 3000 lbs of armament
- [O] Provisions for carrying/deploying a variety of weapons, including rail-launched missiles, rockets, and 500 lb (maximum) bombs
- [R] Integrated gun for ground targets
- [R] Service life: 15,000 hours over 25 years
- [R] Service ceiling: ≥ 30,000 ft
- [R] Crew: Two, both with zero-zero ejection seats

The metrics of success for the project can be seen in Figure 2. The submitted report will be graded by judges on the AIAA Technical Committee which developed the RFP.

Figure 2. Austere Field Light Attack Aircraft Judging (AIAA, 2020).

1. **Technical Content (35 points)**
   This concerns the correctness of theory, validity of reasoning used, apparent understanding and grasp of the subject, etc. Are all major factors considered and reasonably accurate evaluation of these factors presented?

2. **Organization and Presentation (20 points)**
   The description of the design as an instrument of communication is a strong factor in judging. Organization of written design, clarity, and inclusion of pertinent information are major factors.

3. **Originality (20 points)**
   The design proposal should avoid standard textbook information, and should show independence of thinking or a fresh approach to the project. Does the method and treatment of the problem show imagination? Does the approach show an adaptation or creation of automated design tools?

4. **Practical Application and Feasibility (25 points)**
   The proposal should present conclusions or recommendations that are feasible and practical, and not merely lead the evaluators into further difficult or insolvable problems.

A light attack aircraft must be able to carry a payload capable of providing close air support (CAS) and function in intelligence, surveillance, and reconnaissance (ISR) roles. The U.S. Air Force currently does not have a definitive program for light attack planes used in the counter-terrorism struggle. The U.S. Special Operations Command (SOCOM) has decided to purchases two A-29 Super Tucanos from Sierra Nevada and Embraer as well as two AT-6 Wolverines from Textron Aviation for experimentation (Insinna, 2020). These planes could provide CAS in dispersed, dynamic environments like Afghanistan where insurgent, guerrilla warfare takes place. High-cost fighters like the F-35 are not crucial in ugly, low-tech fights where no aerial threat is present (Tucker, 2020). Most damage CAS aircraft experience in these environments is from small arms on the ground. Advanced aircraft like the F-22 and F-35 would be more efficiently used against adversaries like Russia and China where air-to-air superiority is the dominating factor. The current national defense strategy prioritizes the fight against these threats. Investing in light, simpler airframes that are easy to maintain would increase effectiveness in cutting operational costs in uncontested environments.

Thus far, my team has performed a concept-down select for the configuration of the aircraft. This process involved determining functional attributes of the aircraft and ranking corresponding features to be included in the design. After thorough discussion, a tilt wing configuration similar to the Canadair CL-84 Dynavert was agreed upon. This type of aircraft can complete vertical takeoff and landing (VTOL) like a helicopter but is able to fly like an A-29 or AT-6. This design is intended to blend the takeoff and landing versatility of attack helicopters with the survivability and maneuverability of a fixed wing attack plane. We have arrived at an initial estimation of takeoff gross weight of 12,417 lbs using an estimation algorithm from *Fundamentals of Aircraft and Airship Design Vol. 1 (2000)* by Leland Nicolai and Grant Carichner combined with self-written code in MATLAB. The CL-84 had a similar takeoff gross weight of 12,600 lbs (Upton, 2014). Over the course of the next month and spring semester, the specifications of our design will be further refined. Aerodynamic and structural analysis of the design will then be performed using modeling software. Moreover, we will conduct a quantitative assessment of cost to incorporate into our report. I am the team leader for my capstone and my responsibilities largely revolve around communication, facilitation, and tracking of progression.

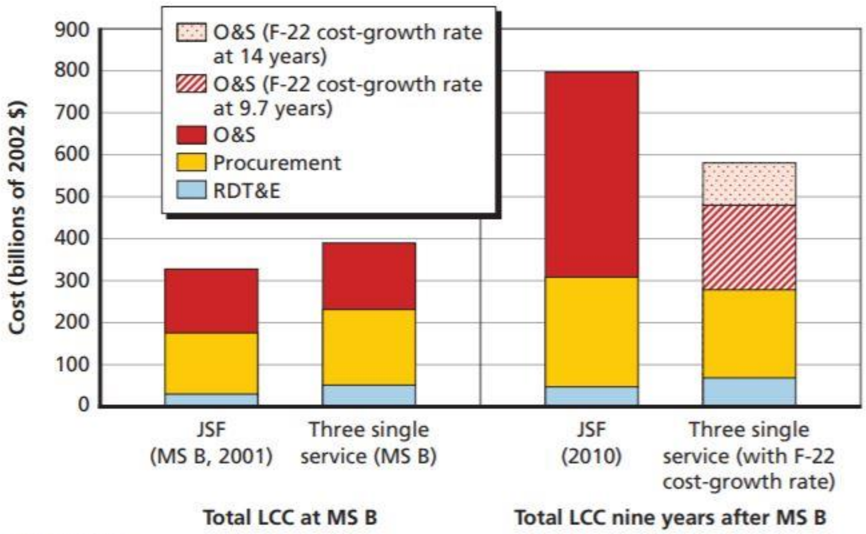
STS Topic

The F-35 program is the most expensive project in the history of the United States military. It is expected to have a 60-year lifespan that would cost taxpayers over $1 trillion dollars (Insinna, 2019). The first supply of F-35s in 2006 cost nearly $241.2 million per plane; more than 3 times the slated $80 million target for the plane initially. As of last year, the F-35A variant is listed at $79.2 million per a contract between Lockheed Martin and the Department of Defense (Lockheed Martin, 2019). This reduction in cost is primarily the result of restructuring and negotiation between Congress and the Department of Defense on the effectiveness of the F-35 Joint Strike Fighter program. A Joint Strike Fighter is intended to replace a wide range of existing aircraft. Developing a multitude of aircraft suited to specific mission profiles could actually be a more cost-effective strategy than attempting to develop one jack of all trades, multi-purpose aircraft.

Many of the issues surrounding the F-35 program are the product of a lack of direction. The Joint Strike Fighter is an attempt to design an aircraft that could do everything as opposed to one thing very well. The aircraft was initially proposed as the next-generation answer for many divisions of the U.S. military from the Air Force to the Marine Corps to the Navy (Hughes, 2017). The effort to share design and replacement parts across different branches of the military caused the cost of the program to skyrocket. Performance is also affected in an attempt to build an aircraft suited to the needs of each branch. One branch’s demands for design specifications may conflict with the demands of another; leading to an aircraft that is suboptimal for each of the services it was originally intended for. A test flight revealed subpar results of the F-35’s performance in a dogfight versus the F-16, an older generation aircraft. The pilot noted a lack of energy maneuverability, insufficient pitch rate, and unintuitive flying qualities when the angle of attack was between 20 and 26 degrees (Axe, 2016). This means that the pilot expected a certain roll rate when controlling the F-35 but the body of the plane itself did not actually achieve the desired input. Not only was commonality targeted across different military branches but also across the three F-35 variants. The initial need for compatibility resulted in compromises for variants in achieving their specific features. For example, the F-35B model was designed for short-takeoff-and-vertical-landing (SVTOL) abilities. However, marine pilots noticed thrust limitations when trying to land the variant onto a ship vertically on hot days when the temperature was over 90° Fahrenheit (Larter et al., 2020).

The main purpose of a joint program is to save overall Life Cycle Cost (LCC). The RAND Corporation completed an analysis of the cost of Joint Strike Fighter programs compared to single-service programs using research sponsored by the U.S. Air Force (Lorell et al., 2013). The results were compiled using a Selected Acquisition Report (SAR) database with information on more than 300 major defense acquisition programs. To properly account for inflation rates, cost growth was measured in dollars of constant purchasing power. RDT&E includes research, development, test, and evaluation (RDT&E) while O&S includes operations and support.

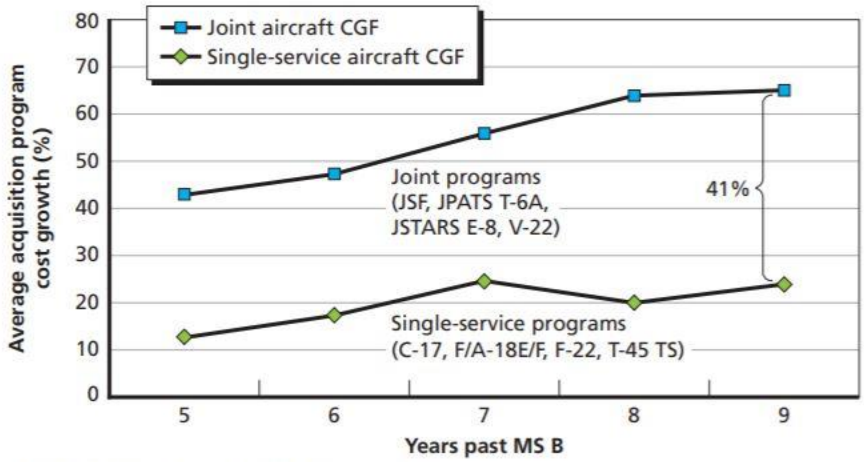
Figure S.1
Estimated Nine Years Past Milestone B, Life Cycle Cost for Joint Strike Fighter Would Be Higher Than Those for Three Notional Single-Service Programs (Assuming F-22 Cost-Growth Percentages)



RAND *MG1225-S.1*

Figure S.1 demonstrates that Joint Strike Fighter programs have significantly higher LCCs than multiple single-service programs. RAND states that "the difficulty of reconciling diverse service requirements in a common design is a major factor in joint cost outcomes." Moreover, there was a 41% percent difference in average acquisition cost growth for Joint Strike Fighter programs relative to single-service programs as seen in Figure 2.1.

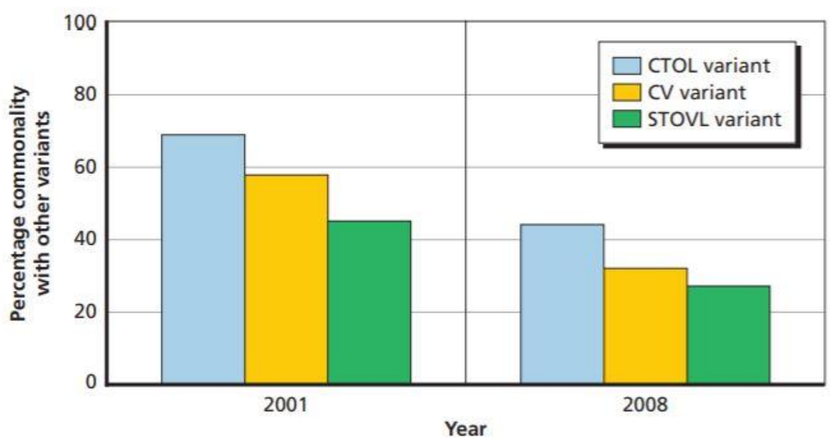
Figure 2.1
Historical Joint Aircraft Programs Have Incurred an Acquisition Cost-Growth Premium Compared with Single-Service Aircraft Programs



SOURCE: Authors' analysis of SAR cost data.
NOTE: CGF = cost-growth factor.
RAND *MG1225-2.1*

These cost growths are largely in part due to the effort to resolve the different objectives across designs that become increasingly complex. Attempting to optimize variants for each service decreases commonality, shifting cost projections further. This trend is depicted for the F-35 program in Figure 3.5.

Figure 3.5
Joint Strike Fighter Structural Commonality Has Declined Since Milestone B



NOTE: We use the CAPE definition of commonality of cousin parts for cost-estimation purposes. Commonality here is measured by airframe structural weight.
RAND *MG1225-3.5*

The F-35A was developed for the U.S. Air Force as a conventional takeoff and landing (CTOL) aircraft (Hubinger, 2019). It is intended to replace the F-16 and the A-10 for air-to-air and air-to-ground support. The SVTOL F-35B is intended to replace the AV-8B Harrier for the U.S. Marines. The F-35C is also a CTOL aircraft that acts as a carrier for the U.S. Navy. Developing one aircraft for different branches of the military while trying to maintain a common design between the models is counter intuitive. As the program progressed over the years, commonality simply became more challenging to maintain and should not have been a primary design objective in the first place. The question is why; why are there unexpected cost growths in military programs and why does commonality decrease? The answer to these questions can be found in military innovation studies. A framework of decision makers, power struggles, motivation, and competition can be outlined using three major models of innovation (Grissom, 2006). The interservice model states that chiefs of staff determine the best course forward and induce service bureaucracy to innovate accordingly. The intraservice model claims that senior service leaders imagine a new theory of victory and then leverage internal politics. The cultural model argues that senior officers position their organizations to achieve innovation that lines up with a personality which blinds some opportunities and gives prominence to others. For example, the Air Force's personality could be described as a fascination with fixed wing flying machines that demonstrate air superiority. All of the above-mentioned models feature top-down innovation, where a vision precedes capabilities. How to develop the technology is often figured out along the way. These models are limited in that they exclude the existence of bottom-up innovation where existing technology was expanded upon. In *The Warthog and the Close Air Support Debate (2003),* Douglas Campbell claims that the Air Force built the A-10 in response to the Army developing the AH-56 Cheyenne attack helicopter because they were afraid that all close air support capabilities would be transferred to the Army. The interservice model of innovation could be used to explain this process however it fails to recognize that the A-10 is an aircraft in which an airframe was essentially built around a 30 mm cannon. The original use of the weapon was not designed as the main armament of a flying machine and yet it ended up flourishing in an air-to-ground combat role.

A reflection on history may explain the current trend towards programs like the F-35. Rivalry within and among the armed services has often been a driver of military acquisition (Alic, 2013). The passing of the 1986 Goldwater-Nichols Act attempted to dampen rivalries and encourage jointness. Consequently, the DoD now has a large focus on joint-strike fighter programs. A key difference between the government and private industry provides some reasoning as to why the inaccurate cost claims and timelines at the proposal of the F-35 occurred. Unlike in government, the private industry typically uses various predictions of effectiveness and cost to place proposals at a common level. The government's lack of practical methods for evaluating the effectiveness of proposed weapon systems is a cause for frequent cost escalation and restructuring. These methods often mediate top-down approaches and the role of the service chiefs. The decreases in commonality in the variants of the F-35 can be linked to the cultural model of innovation and a wish of the different armed services to have a model that fits their personality and vision.

I plan to analyze different examples of military innovation throughout history in an attempt to gather a consensus as to which model applies best to each example. Empirical evidence sources will involve previous military innovation studies and DoD reports on aircraft like AV-8B Harrier and the A-10 leading up to the F-22 and F-35. I am curious as to if there is a trend or shift in the defense strategy that resembles a transition from one model of innovation to another. Is there a model of military innovation that is dominate in the current climate as of today? The research I gather will hopefully be beneficial in a deeper understanding of decision making and problem framing in the military aircraft design process. Stakeholders and actants include the taxpayer, the Department of Defense, the aerospace engineer, the pilot, etc.

Next Steps

- Begin searching for military innovation studies on mentioned specific aircraft
- Find more sources besides just Grissom that break down the different models of military innovation
- Determine which information that has been collected is relevant to the thesis in the beginning of the Spring semester
- Begin writing and incorporating this information into a coherent thesis in the beginning of the Spring semester

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