Prospectus

American Institute of Aeronautics and Astronautics: Light Attack Aircraft Design Competition
(Technical Topic)

Gender Inequality in Aircraft Design
(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.

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Background on Light Attack Aircraft and Gender Inequality in Design

An aircraft that falls into the category of a light attack aircraft (LAA) is one built with low mass so that quick take off and landings are easy and so that the pilot has more control maneuverability. LAA are designed to fly at low-levels and support ground troops with a wide variety of attacking weapons (Britannica, 2017). The first attack aircrafts were produced during World War II when Britain and Germany decided they wanted to destroy tanks and other armored vehicles on the battleground. The first designs were enhanced versions of fighter aircrafts with increased speed, power, protection and durability. Compared to other weaponized aircrafts such as fighter aircrafts or bombers, an attack aircraft is used in tactical and urgent situations (History, 2020).

Currently, the United States Army and Air Force employ two LAA: A-29 Super Tucano and A-T6 Wolverine (AOPA, 2020). They are both low mass but carry a different assortment of armaments to distinguish themselves from each other. Although these aircraft have proven to be successful in their respective missions, there is one limiting design aspect that keeps them from being successful in all types of battle situations. This is the fact that they are not designed to operate from austere fields. An austere field is terrain that lacks ramp space or navigation aids, or has a poor ground surface such as flexible pavement, grass, or dirt. The A-29 and the A-T6 can only fly missions where there is a properly functioning airstrip nearby. The American Institute of Aeronautics and Astronautics (AIAA) is looking to remedy this problem. The 2021 AIAA undergraduate design competition is requesting designs for austere field light attack aircraft to influence the next generation of US military light attack aircraft (AIAA, 2020).

Keeping in line with the topic of aircraft design, this research will also address gender inequality in aircraft cockpit design. The research project will consider how the recertification of military standards and FAA regulations could ameliorate gender inequalities within designs. The technical project will be to submit a state-of-the-art, LAA design that will be capable of operating from austere fields for the AIAA undergraduate design competition.

Light, Attack Aircraft Design

Existing light attack aircraft used by the US Air Force and Army are the A-29 Super Tucano, seen in Figure 1, and A-T6 Wolverine, seen in Figure 2. Both aircraft have a single turboprop engine with seats for two crew members. The A-29 has a service ceiling of 35,000 feet, a maximum range of 2,600 nautical miles, a loiter time of roughly six and a half hours, and a landing distance of around 2,800 feet (Sierra, 2018). The A-T6 has a service ceiling of 31,000 feet, a maximum range of 1,725 nautical miles, and a loiter time of roughly seven and half hours (AOPA, 2020). These performance characteristics are going to have a big impact on the direction that our team will take in regards to the AIAA challenge.

Figure 1. A-29 Super Tucano Light Attack Aircraft. (Image source: Reim, 2020)

Figure 2. A-T6 Wolverine Light Attack Aircraft. (Image source: A-T6 Light Attack, 2018)

The technical project, and proposed solution, is inspired entirely by the AIAA competition to design an austere field light attack aircraft. The mandatory requirements and objectives and goals of the LAA design are outlined in the Request for Proposal published by AIAA. Table 1 reviews the requirements and objectives from the RFP and organizes them.

Category	**Area of Design**	**Description**
Required	Austere Field Performance	Takeoff and land over a 50 ft obstacle in shorter than 4,000 ft when operating from austere fields at a density altitude up to 6,000 ft with semi- prepared runways, such as grass or dirt surfaces with California Bearing Ratio of 5
Required	Payload	3000 lbs of armament (minimum)
Required	Armament Types	Integrated gun for ground targets
Required	Service life	15,000 hours over 25 years
Required	Service ceiling	Greater than 30,000 ft
Required	Crew	Two, both with zero-zero ejection seats
Objective	Survivability	Consider armor for the cockpit and engine, reduced infrared and visual signatures, and countermeasures (chaff, flares, etc.).
Objective	Armament Types	Provisions for carrying/deploying a variety of weapons, including rail-launched missiles, rockets, and 500 lbs (maximum) bombs

Table 1. Requirements and objectives for the 2021 AIAA design challenge (AIAA, 2020).

California Bearing Ratio (CBR) is a system that defines the strength of subgrade of the ground. A CBR of five indicates a low-strength-ground such as dirt, grass, or very flexible pavement. Since the performance characteristics and armaments on the A-29 and A-T6 are similar to the RFP requirements, our team has decided to use their designs as guides for the challenge.

The components of the design challenge that our team has completed are the type of propulsion system and the shape and size of the wings and fuselage. We are currently working to determine the total weight with fuel, which types of armaments to attach, and how we are going to implement austere field protection and prevent foreign object damage. While making all of these design decisions, we are keeping track of total cost and ensuring that the design stays compliant with military standards and Joint Service Specification Guides (JSSGs). These two types of documentation control every aspect of an aircraft's design.

Our technical project deliverable will open up a sect of operating terrains that have historically been off limits for aircraft. Helicopters are typically used in these quick, tactical, battle situations but they do not have the protection nor can they carry the amount of armament that a light attack aircraft has. The winner of this design competition could influence the creation of an aircraft that will provide air support for fighting troops in places like short grass fields, and rocky or clay ground. The act of designing an aircraft can be associated with the topic of gender inequality. A crucial part of the design is the human factors engineering. The pilot has to be capable of flying the machine, otherwise a mission is compromised and a very expensive piece of technology becomes useless. Keeping this in mind, the following section will discuss how aircraft cockpits are restrictive for certain body types.

Gender Inequality Across Civil and Military Aircraft Design

The first modern US civilian aircraft, the Boeing 247, was built in 1933 (Historical, 2020), and one of the first US military combat aircraft, the Boeing B-17 Flying Fortress, was built in 1935 (Richman, 2020). However, females were not legally allowed to attend civilian pilot training programs until 1972 in the US (Davey, 2000), and they were not legally allowed to fly in US military combat missions until 1993 (Smithsonian, 2018). In 1968, when only men were flying aircraft, the DOD Design Criteria Standard for Human Engineering was written

(DOD, 1999). This standard, MIL-STD-1472, contains all of the specifications for aircraft sizing down to the predicted length of a pilot's finger tips. It is necessary to note that males and females universally have different anthropometric measurements. Anthropometric measurements are height, weight, and body circumference. It becomes clear to see how those with smaller body shapes may face difficulties when operating machinery designed and built for larger sized humans.

Small stature bodies, which include around 95% of females and 25% of males, have the following issues when in a cockpit: struggle reaching controls or operating certain equipment, limited sight lines, and buttock-knee length limitations for pedals (Weber, 1997). There is also anthropometric data suggesting that small pilots have difficulties with forward vision over the nose of the aircraft, leg reach to rudder controls, and arm reach to the control panel (Zehner, 2000). Multiple articles and reports suggest that the root cause for these difficulties is the specifications and standards that control the design. This refers to the military standards or Federal Aviation Association rules that designers have to follow so that their aircraft will be deemed 'certifiable' to fly.

The MIL-STD-1472 for human engineering design criteria and the FAA human factors handbook contain design specifications that pose concerns for female pilots. The MIL-STD-1472 has gone through eight revisions since it was first published in 1968, but almost every specification that has a description with the word 'female' in it just says that the requirement "should be corrected, where applicable, for females" (DOD, 1999). This is positive in that the standard acknowledges changes need to be made to eliminate gender limitations in arm, hand, thumb-finger and foot controls (Sections 5.4.4.2 and 5.4.4.3), but it does not provide measures of change for smaller bodies. The FAA safety handbook on human factors (HF) addresses what fields of study HF covers and how HF apply differently to males and females. It states that someone who has a smaller body "may be able to perform more efficiently with equipment that is tailored to their size", suggesting that a one-size design will not fit all pilots that have to use the aircraft (FAA, 2008).

The process of analyzing military standards for gender inequality relates to the technical topic of designing a light attack aircraft. A crucial part of designing our LAA will be to ensure that every shape, size, and material is compliant with airworthiness criteria. If we do not adhere to every regulation, our design will not be certifiable and we will be unable to compete in the design competition. The AIAA design competition does not, however, require teams to design the interior of the aircraft, like the cockpit, so we will not be doing any human factors considerations. The technical project does not incorporate designing part of an aircraft that could create inequalities for female pilots.

The two frameworks I will use for this research topic are the Social Construction of Technology (SCOT) and inclusive design. SCOT is the idea that technological development can be explained as a social process. Social groups that encounter a problem with a technology voice their concerns and then the construction of technology will be improved to reflect the needs of society. In a chapter from the book, *The Social Construction of Technological Systems,* Pinch and Bijker placed the cause of evolution of the bicycle on social groups that demanded the design be altered so that they could utilize the artifact (Bijker & Pinch, 2012). The example of the bicycle can be easily translated to aircraft design. SCOT recognizes females as a relevant social group that use aircraft. SCOT will take into account the knowledge that females are encountering issues with a technology and it will provide an approach for actually ameliorating gender inequality in aircraft design.

Inclusive design, the second framework, suggests that all designs need to "consider the full range of human diversity with respect to ability, language, culture, gender, age and other forms of human difference" (OCAD, 2018). Inclusive design recognizes that one size does not fit all and it pushes the belief that diversity and uniqueness need to play a role in the design of any and all technologies, artifacts, and systems. No person should be discouraged from pursuing a job because the shape of their body limits them from performing successfully. Applying inclusive design to this research topic is an obvious fit. The design of cockpits need to consider female body sizes to be truly inclusive of all pilots. The design of cockpits can become inclusive once the military standards and FAA regulations are recertified.

Research Methods and Data Analysis

This paper will address the question: How can gender inequality in aircraft design be ameliorated with the recertification of rules and regulations which control the design? This question needs to be answered sooner rather than later as the inequality is prohibiting and discouraging some body types from pursuing careers as pilots just because of the shape of his/her body. A large reason why the inequality is still present today can be traced back to the original rules and specifications established to control the design of aircraft.

To get information on the physical difficulties female pilots have faced while in the cockpit of military and civilian aircraft, I plan to conduct interviews with several experienced pilots found via LinkedIn Pilot Group. Interview questions will likely include why and when they decided to be a pilot, how their experience was during training (any physical difficulties using training cockpit simulators), descriptions of when and how they experienced any physical barriers or limitations due to their body size while flying an aircraft, and what types of aircraft they fly/flew. Potential interviewees include Deb Zehner, a former pilot for Continental Airlines in the 1980s, Kristina Himmelreigh, a current pilot in the USAF, Ashley Henderickson, a former US army helicopter pilot, Celia FlorCruz, a former US Army medical evacuation pilot in Iraq, and Sarah Franks, a former USAF aircraft commander and current American Airlines pilot. All are UVA alumni. I also plan to ask them for additional contacts to expand the pool of interviewees. I aim to reach out to them by December 2020, and I'd like to have all of the interviews completed before the spring 2021 semester.

Additional information for this research question will be gathered through a variety of secondary sources. The main sources will be prior literature on gender inequality in cockpits, several reports on the necessity of the recertification Airworthiness Criteria standards, and policy documents such as FAA and MIL-STD aircraft design criteria. The evidence, once found, will be analyzed through consequential case studies and case comparisons. With this form of analysis, the answers from the interviews of female pilots can be compared and contrasted to the prior literature and legal documentation and design regulations to see if and how the recertification can quell gender inequality in cockpit design.

Conclusion

The technical project will result in the design of a state-of-the-art, light, attack aircraft which will be operable from austere fields and also be low cost. Satisfying all of the requirements while also optimizing the cost of production and services will give our team an advantage to win the competition and potentially influence future US military light attack aircraft designs. Having an austere field LAA will open up the doors to providing air support to ground troops in dozens of terrains previously deemed incapable for aircraft.

The science, technology and society research question will address how gender inequality in aircraft design can be ameliorated with the recertification of MIL-STDs and FAA regulations.

Once data for the question is found and analyzed, the expected results of the research paper will show (1) how the recertification of Military Standards and Federal Aviation Administration aircraft design regulations will actually impact gender inequality, and (2) which specific parts of the standards and regulations need recertification.

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