

Protecting Female Pilots: Designing a Cervical Neck Brace to Mitigate Ejection Forces

Female Integration in the Armed Forces: a Wicked Problem

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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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Introduction

Should a female fighter pilot in the U.S. armed forces find herself in a situation where she has to choose between ejecting from an aircraft or going down with it, there will always be a moment of hesitation. She has to choose between permanent spinal injury and certain death.

The U.S military has fighter jets that are exclusively designed for the safety of the 50th percentile male. Should a pilot have to eject, they are inviting a high level of G force to be applied directly vertically along their spine. The vertical force is not strong enough to seriously injure the 50th percentile male, but smaller aviators, most often female, are at an extremely high risk of life threatening or paralyzing injury – because the seat was designed to clear the male pilot from the plane without injuring him (Salzar 2009). These ejection seats have never been updated to support the addition of female pilots into the armed forces, even though the first woman became a fighter pilot in 1993 (Clash 2020). As the military has changed to open its doors for women to join, their technology has not evolved to do the same. It is a dangerous and foreboding cycle that is nearly insolvable: because the military is majority men, technology develops around their safety, and it remains difficult for women to be truly integrated into the military.

A brace designed for female fighter pilots could protect their upper spine from serious injury during ejection. A neck brace made of material that stiffened with the high G force would not impair their range of motion during flight, and could be the difference between life and death upon ejection, effectively integrating the fighter fleet for women.

Cervical Neck Brace: Mitigating G-Forces

The ejection seat mechanism within fighter platforms (F-#) was designed so that the 50th percentile male could survive the G-force applied vertically to the spine (Salzar, 2009). There is a fine line that exists within this applied G-force: it must be great enough to clear the pilot from the plane, while not so great that it does irreparable damage to the spine of the pilot. The fine line G-force quantification was modeled and created based off of cadaver labs only examining the 50th percentile male, and no forward research has been done to accommodate the smaller, often female, pilot – if the average military woman were to eject from a fighter plane, her spine would more than likely be permanently damaged (Salzar 2009). The military has not fixed this glaring issue under the assumption that most of their pilots are male, and their female pilots must sign waivers on the greater risk of their life than their male counterparts. The waivers currently required are entirely weight based, and the military most often will not approve them except under extenuating circumstances: which is why the female fighter population is at a stagnant and startling three percent (McCullough 2020). Research conducted outside of the scope of the 50th percentile male, and the implementation of new technologies such as a neck brace, would help break through the glass ceiling of the aviation community.

There are technologies that can be implemented into the military to make it safer for women to fly fighter jets, in lieu of an entirely new ejection seat and mechanism. Current military technologies, such as anti-gravity suits (brace-like protection worn by fighter pilots), are specifically designed to only stiffen when activated by high levels of G-force so as not to impede the pilot during a normal flight (Pawlyk 2020). A brace that were to activate upon only the highest level of G-forces against the spine would help mitigate the dangers that female pilots face upon ejection, and could effectively help the fighter pilot aviation platforms within the military to become fully open to female pilots. Electroactive polymers, or an EAP, is a material

that only stiffens when activated by an electrical current. When not activated, the material is pliable and non invasive: a property essential to the mission of pilot. Research done through modeling the spinal cord based on anthropometric measurements as small as the fifth percentile female can be applied to the design of the neck brace, and the product can be tested using vertical loading crash simulation dummies to analyze the mitigation to the breakeage of the cervical spine. Once testing is finished, the finalized prototype of the brace as well as a technical report of the lab findings will be presented.

Female Integration in the Military

How can the military utilize sociotechnical systems to better integrate females into the military? Women have been officially in the military for years – ever since 1948, when President Harry S. Truman signed the Women’s Armed Services Integration Act (Gorbulja-Maldonado, 2020). Even before that, women in America have been serving in limited and often hidden roles since the founding of the country: women like Margaret Corbin disguised themselves to effectively fight in the front lines of the Revolutionary War. And yet, 73 years after the military became ‘integrated,’ the number of women hovers at around sixteen percent (Insinna 2021). There are sociotechnical systems at play that effectively bar the military from achieving full integration: uniforms, barracks, and even obstacle courses are built so that they are navigable for the 50th percentile male. Because of the historic and continuing technical design of the military, the societal issue of integrating women remains a difficult, nearly insolvable issue.

Women have been flying planes and been in the military for years, and yet, the number of female fighter pilots across the military has remained largely stagnant. Planes and

cockpits designed in the 1960s for the 50th percentile male have never been redesigned, and they come with height and weight requirements that are extremely restrictive to the female population, especially within the military. The minimum weight of a fighter pilot in the U.S. Navy is 160 pounds, and to fit the anthropometric standards of the aviation community, women must be five feet, nine inches: a height only reached by approximately ten percent of the female population (Alyson 2020). Visibility of female fighter pilots is extremely low, due partially to the restrictions placed on size, and due partially to the fact that women have not been fully integrated into the fighter fleet the way they have been in both cargo and rotary wing platforms. Societal issues within the military are also obstacles to full integration, and the issues emerge within a community that prides itself on being extremely masculine: there were 998 cases of sexual assault in the United States Marine Corps in 2017 (Snow, 2019).

Both the sociological and technological systems that develop within the military keep the number of women that are successful in joining the forces permanently low: and when women constitute a severe minority, systems within the military continue to develop to benefit only their male counterparts. The cyclical nature of the developing systems, combined with the near universal history of the military and other fighting forces being a ‘man’s job,’ makes the integration of women into the military a wicked problem. A wicked problem is defined by an issue, usually conservational or political, where the solution is hard to define, as it is dependent on the issue itself (Seager 2011). Wicked problem framing attempts to create solutions to the problem based on the perceived insolvable nature – common resolutions include shifting or decreasing the stakeholders, or increasing the scope of the population involved in solving the issue (Roberts 2000). Critics of wicked problem framing are quick to claim that none of the

aforementioned resolutions do much to help issues defined as wicked: instead, they present imperfect solutions that are incompatible with the nature of the issue itself, and therefore only small improvements are realistic in practice (Termeer 2019). However, small improvements, especially within wicked problems with a cyclical nature, are unobjectively better than no improvement: as small improvements are made, the cycle becomes closer and closer to being broken (Asdal 2007).

Methods

To conduct research into female integration in the military, the sociotechnical systems within it along with their development over time can be analyzed using wicked problem framing. There are multiple cases of the cyclical nature of the issue within the military: the submarine fleet within the U.S. Navy is not tangibly integrated to women, as fast attack submarines quite literally do not allow women to deploy onboard due to the lack of female bathrooms built into the submarine (Faram 2019). The issue has no planned fix, as not enough women have joined the submarine fleet to warrant spending the money on integration issues. Small restrictions such as the submarine fleet contribute to the overarching wicked problem of integration, and such restrictions must be identified, analyzed as their own wicked problem, and applied to a larger model of the military. Once the model is created, solutions to the larger issue can begin to be mapped out.

Attempting to better integrate the military to women is extremely important: though expecting the armed forces to reach a fifty-fifty representation may always be improbable, a percentage of more than sixteen would be beneficial to the fighting force itself. Diversity within the military, especially within differences in problem approaching and leadership, has been

proven to create a stronger and resilient culture (Fanning 2016). Despite this, the military is arguably the last aspect of society to match any forward societal momentum. Don't Ask, Don't Tell, the law that disallowed openly gay people from serving in the armed forces, was not lifted until 2008 (Franklin 2021). The military academies were the last colleges to integrate by gender, and the military did not let females into front line battle (which includes combat flying) until the 2015 (Gorbulja-Maldonado 2020). There is *still* heavy criticism of allowing women into combat, arguments that stem from a perceived threat of unit cohesion and combat effectiveness (Trobaugh 2018). The military has been and continues to be a 'boys' club,' even as technology steers combat from pure physical strength into intellectual domain.

Conclusion

To make the fighter pilot platform more accessible to females in the military, a neck brace has been designed to protect the cervical spinal cord upon ejection from a fighter jet. The brace is nonintrusive and pliable so as to not impede the mission of the pilot until an electrical current, induced from a pressure sensor tuned to high G-forces, is run through the material. Such a brace should be able to make military waivers based on weight less stringent, and allow more females to fly fighter aircraft. The military's female integration as a whole is addressed as an overarching wicked problem, and smaller issues of integration are researched to better define the issue itself to attempt to find probable solutions to break out of the cyclical nature of the larger problem.

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