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26 ▶ Manufacturing gender in military cockpit design

Rachel N. Weber

Recent work in both science and technology studies and feminist theory has focused on the military as an institution which has both guided technological development and has had a historic claim to masculinity (Cooke and Woolacott 1993; MacKenzie 1990; Law and Callon 1988; Roe Smith 1985; Enloe 1983). In attempting to dissect the historic link between militarism and male power, however, many feminists have accepted the biologically determinist notion that military technologies – the instruments of war – are extensions of the phallus and inextricably linked to the inherently male drive to dominate (Wheelwright 1992; Brownmiller 1975). If we were to apply a less deterministic framework to understanding military technologies, we might find that the 'inherent' masculinity of such technologies is socially constructed. For example, Pentagon officials and engineers have traditionally built a bias against women's bodies into the military technologies through the construction of engineering specifications and design guidelines [1]

Many scholars of gender and technology have questioned women's access to particular technologies (Wajcman 1991). In the context of military aviation, one would ask questions regarding women's upward mobility in the profession; for example, are women limited because they are not trained, socialized, or permitted to fly certain aircraft? Solutions to these problems would lie in eroding barriers to these boundary markers, such as easing women-in-combat exclusions or other operational requirements.

A second approach – and the one which informs the subject of this article – asks questions about the technology itself. How are cockpits designed to accommodate women's bodies? When is a particular flight deck 'gender neutral,' and when is male bias embodied in the actual design, in the engineering specifications? How can biased technologies be altered to become more 'women friendly'?

Design bias is not restricted to the military; commercial technologies such as aircraft, automobiles, and architecture are also built to accommodate male anthropometry. Civilian and military contractors, however, have exhibited different degrees of commitment to the task of accommodating female operators into the design phase. Ironically, in the field of airframe manufacture, civilian contractors are lagging behind their military colleagues in attempting to rectify the problem of design bias against women; the Pentagon has led the movement to alter cockpit design to accommodate women and smaller-statured men . . .

TECHNOLOGICAL BIAS IN EXISTING AIRCRAFT

Civilian and defense aircraft have traditionally been built to male specifications (Binkin 1993). Since women tend to be shorter, have smaller limbs and less upper-body strength, some may not be accommodated by such systems and may experience difficulty in reaching controls and operating certain types of equipment (McDaniel 1994). To understand how women's bodies become excluded by design and how difference becomes technologically embodied, it is necessary to examine how current military systems are designed with regard to the physical differences of their human operators.

To integrate the user into current design practices, engineers rely on the concepts of ergonomics and anthropometrics (McCormick and Sanders 1982). Ergonomics, also called 'human factors,' addresses the human characteristics, expectations, and behaviors in the design of items which people use. During World War II, ergonomics became a distinct discipline, practiced predominantly by the U.S. military. Ergonomic theories were first implemented when it became obvious that new and more complicated types of military equipment could not be operated safely or effectively or maintained adequately even by well-trained personnel. The term 'human engineering' was coined and efforts were made to design equipment that would be more suitable for human use.

Anthropometrics refers to the measurement of dimensions and physical characteristics of the body as it occupies space, moves, and applies energy to physical objects as a function of age, sex, occupation, and ethnic origin and other demographic variables. Engineers at the Pentagon and at commercial airframe manufacturers rely on the U.S. Army Natick Research Development and Engineering Center's '1988 Anthropometric Survey of Army Personnel,' in which multiple body dimensions are measured and categorized to standardize the design of systems. The Natick survey contains data on more than 180 body and head dimension measurements of a population of more than 9,000 soldiers. Age and race distributions match those of the June 1988 active duty Army, but minority groups were intentionally oversampled to accommodate anticipated demographic shifts in Army population (Richman-Loo and Weber 1996).

Technological bias within defense aircraft

Department of Defense acquisition policy mandates that human considerations be integrated into design efforts to improve total system performance by focusing attention on the capabilities and limitations of the human operator. In other words, the Defense Department recognizes that the best defense technology is useless if it is incompatible with the capabilities and limitations of its users. In the application of anthropometric data, systems designers commonly rely on Military Standard 1472, 'Human Engineering Design Criteria for Military Systems, Equipment and Facilities.' Like the use of military specifications in the procurement process, these guidelines are critical in developing standards; they embody decisions made which reflect the military's needs and goals and are ultimately embodied in the technology (Roe Smith 1985).

These guidelines suggest the use of 95th and 5th percentile male dimensions in designing weapons systems. Use of this standard implies that only 10 per cent of men in the population will not be accommodated by a given design feature. If the feature in question is sitting height, the 5 per cent of men who are very short and the 5 per cent who are very tall will not be accommodated.

Accommodation becomes more difficult when more than one physical dimension is involved, and several dimensions need to be considered in combination. The various dimensions often have low correlations with each other (e.g., sitting height and arm length). For example, approximately 52 per cent of Naval aviators would not be accommodated by a particular cockpit specification if both the 5th and 95th percentiles were used for each of the thirteen dimensions.

Because women are often smaller in all physical dimensions than men, the gap between a 5th percentile woman and a 95th percentile man can be very large (Richman-Loo and Weber 1996). Women who do not meet requirements are deemed ineligible to use a variety of military systems.

The case of the Joint Primary Aircraft Training System (JPATS), used by both the US Navy and the Air Force to train its pilot candidates, has been the most publicized case of military design bias against women.[1] Engineers and human factors specialists considered minimum anthropometric requirements needed by an individual to operate the JPATS effectively and wrote specifications to reflect such requirements. For example, 'the ability to reach and operate leg and hand controls, see cockpit gauges and displays, and acquire external vision required for safe operation' was considered critical to the safe and efficient operation of the system. Navy and Air Force engineers determined the five critical anthropometry design 'drivers' to be sitting height, functional arm reach, leg length, buttock-knee length, and weight (Department of Defense 1993: 2).

Original JPATS specifications included a 34-inch minimum sitting height requirement in order to safely operate cockpit controls and eject. This specification is based on sitting height minimums in the current aircraft fleet and reflects a 5th percentile male standard. However, at 34 inches, anywhere from 50 to 65 per cent of the American female population is

excluded because female sitting heights are generally smaller than male. Therefore, JPATS, as originally intended, accommodated the 5th through 95th percentile male, but only approximately the 65th through 95th percentile female.

After successful completion of mandatory JPATS training, student pilots advance to intermediate trainers and then to aircraft-specific training. Therefore, if women cannot 'fit' into the JPATS cockpit or if the cockpit does not 'fit' women pilots, they will be unable to pursue aviation careers in the Navy or Air Force. In other words, design bias has far-reaching implications for gender equity in the military.

Technological bias within commercial aircraft

Despite a similar technological base, the cockpit technology encountered in civilian aviation differs from that found in the military. The role of the human being and the control processes available to him or her also will differ. For example, the extreme rates of acceleration experienced in military cockpits require elaborate restraining devices. Such restraints must be designed to fit the anthropometric characteristics of the intended users. Ejection is also an issue limited to military cockpit design. Much of the JPATS controversy centers on ejection seats and the need to provide safe ejection to lighter individuals.

In contrast, commercial aircraft do not reach the same high speeds as military planes, nor do they contain ejection seats. The seats in a commercial cockpit are adjustable to meet the varied comfort and safety requirements of the users. Thus certain anthropometrics such as height, weight, and strength do not have the same valence in commercial aviation as they do in the military. Many argue that commercial aircraft can accommodate a more variable population because the operating requirements are not as stringent as in the military.

However, the location of various controls on the commercial flight deck has been found to disadvantage women and smaller-statured men (Sexton 1988). Although the seats are more adjustable, individuals with smaller functional arm reach and less upper-body strength may still experience difficulties manipulating controls and reaching pedals. When smaller women are sitting in the co-pilot seat, some complain that they are not able to reach controls on the right side of the control panel. Reach concerns become increasingly important during manual reversion (when the system reverts to manual operation) even though electrical and hydraulic systems require smaller forces to actuate.

Cockpit design specifications have protected what has traditionally been a male occupation. Because both commercial and defense aircraft have been built for use by male pilots, the physical differences between men and women serve as very tangible rationales for gender-based exclusion. Although technology certainly is not the only 'cause' of exclusion and segregation, biased aircraft act as symbolic markers, used to delineate the boundaries between men's and women's social space. Reppy (1993: 6) notes that

> it is not that women are not physically capable of flying these particular aircraft or that they are not equally exposed to danger in other aircraft; rather denying women access to combat aircraft is a way of protecting a distinctly male arena. The technical artifact . . . has functioned to delineate the 'other.'

REGULATING ACCOMMODATION IN DEFENSE AIRCRAFT

The decision to standardize any technology is often contested, occurring within a space where social, economic, and political factors vie for position. In this case, standardization involved altering technologies in order to adjust to a changed sociopolitical environment. In the military, cockpit technology had to be adjusted to the entry of women into the armed forces and their new roles within the services. The process of design accommodation in the military became a process of negotiation between various social groups who held different stakes in and interpretations of the technology in question (Pinch and Bijker 1984).

One could argue that negotiations over accommodation arose as a result of changes made in policies regarding women in combat. Former Secretary of Defense Les Aspin publicly recognized that women should play a greater role in the military when he issued a directive in April 1993 on the assignment of women in the armed forces. The directive states that

> the services shall permit women to compete for assignments in aircraft, including aircraft engaged in combat missions.
>
> The Army and Marine Corps shall study opportunities for women to serve in additional assignments, including, but not limited to, field artillery and air defense artillery.
>
> (Aspin 1993: 1)

Although the new policy gave women a greater combat aviation role and was intended to allow for their entry into many new assignments, the aircraft associated with these assignments precluded the directive from being implemented. The realization that existing systems could contain a technological bias against women's bodies despite the Congressional mandate for accessibility alarmed policy specialists at the Pentagon. This contradiction would potentially embarrass a new administration which was reeling from its handling of the gays in the military debacle and desperately trying to define a working relationship with an antagonistic Pentagon.

In May 1993 the Under Secretary of Defense (Acquisition) directed the Assistant Secretary of Defense (Personnel and Readiness) to develop a new JPATS sitting height threshold which would accommodate at least 80 per cent of eligible women. He delayed release of the JPATS draft Request for Proposal until a new threshold could be documented. This move led to the establishment of the JPATS Cockpit Accommodation Working Group which included representatives from the Air Force and Navy JPATS Program

Offices as well as from service acquisition, personnel, human factors, and flight surgeon organizations. After months of deliberation, the Working Group determined that a reduction of the sitting height requirement by 3 inches would accommodate approximately 82 per cent of the eligible female population (Department of Defense 1993).

Reducing the operational requirements would entail modifying existing cockpit specifications. Significant modifications were needed because the requirement for an ejection seat restricts the possibility of making the seat adjustable. In addition, the aircraft nose, rudder, and other flight controls would also need to be substantially modified to accommodate a smaller person. Further, since ejections at smaller statures and corresponding body weights had yet to be certified for safety, test articles and demonstrators had to be developed to ensure safe ejection (Dorn 1993).

After the May 1993 directive, many procurement specialists at the Pentagon were perplexed: a design which would accommodate the 5th percentile female through the 95th percentile male would have to incorporate a very wide variability of human dimensions. Some senior defense officials opposed such a change because they believed that such alterations would delay the development of the JPATS, would raise the price of training, and would be prohibitively expensive.

In opposition to these officials, pragmatists within the Pentagon – including most members of the Working Group – argued that it was both efficient and economical to integrate human factors into acquisition. Pragmatists felt that the technologies built for the military, as opposed to civilian markets, tended to privilege capability over maintenance and operability and hardware over personnel. They argued that with decreasing budgets, this could no longer be the case. Design changes, they claimed, would not only benefit women assigned to weapons systems originally designed for male operators, but would benefit smaller men as well. Studies have shown that smaller men also have difficulty operating hatches, damage control equipment, and scuttles on ships (Key, Fleischer and Gauthier 1993). Shrinking personnel resources and a changing demographic pool from which the military recruits also mandated that defense technologies be more closely matched to human capabilities. The pragmatists were quick to emphasize that the inclusion and accommodation of smaller men would be necessary given changes in the ethnic and racial make-up of the nation (Stiehm 1985).

Pragmatists also pointed to the prospect of foreign military sales to countries with smaller-sized populations, which would make design accommodation an important economic consideration as well. Edwin Dorn (1993), the Assistant Secretary of Defense, in a memorandum to the Under Secretary of Defense (Acquisition), stressed that

> a reduced JPATS sitting height threshold will also expand the accommodation of shorter males who may have previously been excluded from pilot training. For potential foreign military sales, this enhances its marketability in countries where pilot populations are of smaller average stature.

The pragmatists emphasized that cockpit accommodation would benefit all soldiers because it required the acquisition process to consider differences concerning capabilities and limitations. In pursuing this line of argument, they essentially neutered the discourse, erasing the specificities of women's bodies. By refusing to engage in a gendered discourse and instead emphasizing economic benefits, they hoped to appeal to a broader segment of the population and to a Pentagon traditionally hostile to women's issues.

In contrast to the Pentagon pragmatists, women's groups both within the military and outside supported the decision to alter the JPATS sitting height requirement on more ideological grounds. The fact that women were being excluded by the operational requirements and by the technology was central to their decision to support the changes. In general, feminism in the contemporary military environment is organized around ideals of parity and equal opportunity regarding career opportunities (Katzenstein 1993). Insisting that career advancement be based on qualifications, not biology, many argued that physical restrictions which disqualified women would unfairly limit women's mobility in the services.

Through informal networks and more formal associations such as the Defense Advisory Committee on Women in the Service (DACOWITS), new groups of activists set about to influence policy decisions about career opportunities for women. Women aviators organized around the issue of female accommodation and found a receptive audience in some of the new Clinton appointees, such as Edwin Dorn, Assistant Secretary of Defense. Unlike other changes imposed from the top, the decision to alter JPATS was part of a low-level process that began with limited intervention from high-ranking administrators (Brundage 1993).

Although the media spectacle of the Tailhook scandal[2] provided the necessary momentum for feminist groups in the military and brought gender issues to the forefront of national debates, the decision to accommodate more women in the JPATS cockpit was not without dissension. Some women officers – many of whom also considered themselves feminists – believed that, as one of the people I have interviewed told me, 'shrill cries for accommodation could be used against women politically.' They insisted that demanding special treatment would single women out in an institution which, on the surface, seeks to eradicate differences between the sexes. In a sense, they were asking women to ignore their difference and prove themselves on gender-neutral terms.

A few women pilots questioned the construction of the operational requirements and thresholds but insisted that the existing cockpits were not biased. Is it really necessary, some asked, to possess a sitting height of 34 inches to fly defense aircraft? Women with smaller sitting heights had flown during wartime, and many believed that pilots at shorter sitting heights were no less capable of flying safely. One woman claimed that 'the whole issue of height in aircraft is overstated, and just ignorance on the part of the Navy.'

As debates raged in the press and within the Working Group during 1993, the possibilities for technological variety began to close down. The Pentagon pragmatists attempted to stabilize the debate, but the public spectacle

of the issue facilitated closure by broadening the deliberative arena. With the JPATS case, 'administrative' closure was achieved when the 1994 Defense Authorization Bill was passed. The bill included a provision which prevented the Air Force, the lead agency in the purchase of the JPATS, from spending $40 million of its $41 6 million trainer budget unless the Pentagon altered the cockpit design. John Deutsch (1992), then the Under Secretary of Defense, wrote a memo legitimizing the problem of accommodation of women in defense aircraft, stating:

> I believe the Office of the Secretary of Defense (OSD) should continue to take the lead in addressing this problem. Other platforms in addition to aircraft should be considered as well. We must determine what changes are practical and cost effective in support of Secretary of Defense policy to expand combat roles for females. I request that you take the lead in determining specification needs. Further, you should determine the impact of defense platforms already in production and inventory.
>
> (Deutsch 1992: 1)

After Working Group deliberations, the Air Force issued a revised JPATS Draft Request for Proposal that included a 32.8-inch sitting height threshold. The RFP identified crew accommodation as a key source selection criterion so that during the selection process, prospective contractors would be required to submit cockpit mock-ups which would be evaluated for their adherence to the revised JPATS anthropometric requirements. Candidates who adhered to and even exceeded these requirements stood the best chance of winning the contract.

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NOTES

1 As there is a pronounced dearth of research in the area of gender and cockpit design, this project relies heavily on interviews conducted with human factors specialists at major airframe manufacturers (primarily Boeing and McDonnell Douglas), public sector research laboratories, and regulatory agencies. Because interviews were conducted during the very competitive source selection phase of procurement, interview subjects were reluctant to discuss this subject unless they were guaranteed strict anonymity. Due to these constraints, I have chosen to paraphrase interviews rather than use direct quotations

2 The Tailhook scandal refers to the annual Tailhookers' (Navy carrier pilots) convention of 1991 where several women were sexually harassed by servicemen and

later went public with their charges As a result, three admirals were disciplined, although none of the servicemen were officially charged

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