Manufacturing Gender in Commercial and Military Cockpit Design

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Based primarily on original interviews, this article compares the treatment of gender as an ergonomic consideration within military and commercial cockpit design. Both defense and civilian cockpits have traditionally been built to engineering specifications based on male anthropometry and tend to embody a physical bias against women and smaller-statured men. However, the design of defense aircraft has been more highly regulated, and more efforts have been taken to ensure that a larger pool of otherwise eligible female pilots are accommodated by future systems, such as the Joint Primary Aircraft Training System (JPATS). The article demonstrates how and why the interests of women pilots could prevail in the traditionally male preserve of the military.

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 deterministic 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

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built a bias against women's bodies into the military technologies through the construction of engineering specifications and design guidelines.

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. In the following pages, I will trace the treatment of a decision to alter technology—the accommodation of women pilots in cockpit design—in civilian and military airframe manufacture. I will demonstrate how and why the interests of women pilots prevailed in the traditionally male preserve of the military.

The discovery that existing cockpits embodied a bias against women and smaller-statured men received different responses from those manufacturers who contracted with the state and those who contracted with commercial airlines. Although often housed within the same private firm, military and commercial procurement are institutionally distinct; contractors often maintain separate divisions, facilities, accounting procedures, and organizational hierarchies. Rather than reify or overstate this distinction, I hope to explore how the boundary between public and private production operates to construct certain issues as open to lobbying (i.e., "political") processes and others as dependent upon market forces. When the state is the consumer, as in military procurement, the issue of design accommodation is viewed as "political," and hence open to negotiation by various interest groups and to control though the legislative process. Within the private realm of commer-

cial production, this issue is viewed as "economic," reduced to questions of managerial preference, quantitative calculus, and threat of legal liability.

The first section of this article lays out the technological problem: that the design of civilian and military cockpits and their attendant operating requirements tend to exclude women and shorter-statured men. I rely on interviews and internal documents to trace the case of the Joint Primary Aircraft Training System (JPATS), which has received the attention of Congress and the American popular media in the past three years.[1] I then examine the existing regulatory processes which could remedy such problems in military and commercial production, respectively. To understand why the regulation of military aircraft has been more extensive and effective, I delve into the ideological assumptions which inform notions of private and public accountability.

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 percent of men in the population will not be accommodated by a given design feature. If the feature in question is sitting height, the 5 percent of men who are very short and the 5 percent 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 percent 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) has been the most publicized case of military design bias against women.[2] 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 percent 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

Engineers design commercial cockpits based on military specifications, aiming to accommodate a population ranging from 25th percentile military women to 99th percentile military men. The methods used by human factors practitioners in the commercial world to determine accommodation are quite similar to those used by the military, many having been developed by internal defense divisions or borrowed directly from the public sector research laboratories (Weber 1995). Using computerized human modeling packages, engineers are able to analyze visibility and reach in a proposed cockpit design. Such programs create three-dimensional graphic representations of pilots which can be adjusted to different body sizes and proportions based on accumulated anthropometric data from the Army surveys, such as those published by the U.S. Army Natick Research Development and Engineering Center.

Although military and commercial engineers use similar methods and data, their pilot populations may differ. Commercial aviation relies on anthropometric data representative only of military populations, even though a different pool of pilots may be flying commercial planes. Many of the human factors engineers interviewed maintained that one of the obstacles to overcoming design bias against commercial women pilots is the lack of comprehensive anthropometric data for civilian female populations. The only available civilian anthropometric data are very old; for female measurements, some manufacturers still use a 1940 Department of Agriculture survey conducted for clothing dimensions. Human factors engineers agree that these data are not extensive enough for use in designing large, complex interfaces such as cockpits.

Commercial manufacturers do not possess conclusive data regarding the total population of women commercial pilots, let alone their body dimensions.[3] Approximately 3 percent of all pilots in the U.S. are women, and the percentage is significantly lower worldwide (Gilmartin 1992). In 1990 the Air Line Pilots Association (ALPA) estimated that there were approximately 900 women pilots (out of a total of 43,000) at forty-four of the airlines where it had members at that time. However, the number of women earning their air transport rating in the United States has increased by 325 percent since 1980.

Human systems specialists suspect that the civilian pilot population is more varied than the military because civilian airlines have less restrictive eligibility requirements. Commercial airlines do not maintain the same limits on body weight and height as the military. Moreover, in the military most pilots are between twenty-one and thirty-five years old, whereas commercial airlines employ an older population, often composed of retired servicemen.[4] This results in a less standardized commercial pilot population, one that might not be represented in the anthropometric data culled by the military.

Principal airframe manufacturers, such as Boeing and McDonnell Douglas, contract with both the government and private airlines. Much of the technology base, supplier base, skills, and processes used by defense and civil aircraft are common even though the divisions responsible for military and civilian work are organizationally and physically separate (Markusen and Yudken 1992). Whereas the defense division responds to a single client—the Pentagon—whose main concern is the performance characteristics, the concerns of the commercial division focus primarily on production costs or marketing (Melman 1983; Markusen 1985).

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 percent 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 percent 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 makeup 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.[5] 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 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.[6] 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 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.

As the preceding case reveals, the relevant social groups who had a stake in changing the technology were able to voice their interests in quasi-public fora: in legislative committees, in the JPATS Working Group meetings, and in the popular media. The debates surrounding accommodation exposed the interpretive flexibility of cockpit design but also demonstrated how the more powerful and pragmatic groups were able to push forth their agenda. Able to increase momentum because of intersecting debates on "women in combat," the Working Group cast the issue of altering military technologies in terms of accommodating all types of operators and emphasized the political accountability of a public consumer to these operators.

Regulating Accommodation in Civilian Aircraft

My research suggests that engineers in civilian aviation are lagging behind their military colleagues in the general field of human factors research. With specific regard to the accommodation of female pilots, most of my interview subjects agreed that the military has taken the lead in evaluating (wo)man-machine interaction and is actively attempting to eliminate male bias in design. Whereas the accommodation of women pilots in military aircraft depends on the relative power of interest groups and political directives, in the commercial sector the issue of female accommodation lies at the intersection of technological capability, labor relations, and profit margins.

In commercial aviation, the process of designing and developing a cockpit is different for each manufacturer and for each aircraft. Because commercial airframe manufacturers design for various customers, they must incorporate the preferences of each individual customer airline into their designs. Unlike defense procurement contracts, the only regulations that standardize the design of cockpits with respect to human factors emanate from the Federal Aviation Administration (FAA) and are found in the Federal Aviation Regulations (FAR), Part 25.777C:

> The controls must be located and arranged with respect to the pilot seats so that there is full and unrestricted movement of each control without interference from the cockpit structure or the clothing of the minimum flight crew (established under 25.1523) when any member of this flight crew from 5'2" to 6'3" in height is seated with the seat belt and shoulder harness (if provided) fastened.

The regulations make no mention of the gender of the intended user, but manufacturers interpret them to include both male and female pilots.

Manufacturers are required to write a report, complete with mock-ups and models, stating that the design complies with FAA physical requirements. Many believe, however, that the FAA guidelines are limited by their lack of enforcement and by their ambiguity—for example, standing height may not be the sole design driver or determinant of accommodation. The FAA rarely attempts to verify that smaller pilots are accommodated in the cockpits.

Manufacturers are responsive to their carrier customers within these loose FAA guidelines; they will consider the accommodation of women and smaller-statured people in any design, but just how much of an issue it becomes—how big the envelope, how adjustable the seat—depends on the particular customer's preference. Aware that changing designs will raise manufacturing costs and subsequently prices, customer airlines rarely voice

concern about accommodating women pilots specifically.[7] Customers have traditionally been more concerned with profit or payload motives, such as the number of passenger seats and cargo capacity, than with cockpit requirements.[8]

Some domestic airlines have queried height requirements and other human factors issues in the context of labor relations and employment discrimination. Carriers' legal departments have occasionally contacted manufacturers out of a fear that the airline will be sued for employment discrimination because height and strength requirements for pilots are so high as to exclude a significant number of women.[9] For example, a woman pilot trainee who failed a simulator test might claim that the airline, and possibly the aircraft itself, are biased against those with lower upper-body strength. The airlines fear that they will be unable to justify such requirements as bona fide occupational qualifications critically related to job performance. Consequently, they may be liable under Title VII for gender discrimination.

Since the energy crisis of the mid-1970s and the Airline Deregulation Act of 1978, the American airlines have been engaged in a competitive struggle to cut costs (Stone 1990). Such changes have intensified the conflict between labor and management as new nonunion airlines entered the industry, forcing unionized carriers to match their discounted fares and costs. Management has insisted that unions such as the Air Line Pilots Association (ALPA) make concessions, but has been unable to ensure job protection in return. Few new pilots have been hired in the past decade, and those who do hold temporary and permanent positions do not feel assured of their job tenure. Cockpit design issues are less likely to make it to the bargaining table in an environment where traditionally male-dominated unions are engaged in bitter wage and terms negotiations.

Although airframe manufacturers who also build defense aircraft have become sensitized to the issue of accommodation in commercial planes, they are not compelled to build women into the engineering specifications. To date, none have explicitly done so. Customer preference and a vague fear of litigation provide the only incentives for altering cockpit technology. Private airframe manufacturers are accountable to the management representing their airline customers, many of whom are either not concerned about this issue or do not receive sufficient input from their line pilots or from the pilot's union.

Public and Private Mandates for Inclusion

Although the accommodation of women in cockpit design is technically feasible, it can be very costly to retrofit existing technology or to build new

systems from scratch.[10] Left to their own devices, private contractors do not design cockpits to fix female anthropometry because there is no incentive to raise their own costs.[11] What, then, activates customer requests for inclusive technological alterations? Part of the answer lies behind the different construction of criteria for and processes of public and private decision making. Whose intervention is considered legitimate and who is held accountable depends upon whether or not consumers are public or private entities.

To understand why the specifications regulating defense contractors are more stringent and more inclusive, we must first consider the distinctive form of what is produced in the public sector. The public sector equivalent of a commodity is a "public good" which, according to neoclassical economic theory, is a collectively valued good or service which is both nonexcludable and nonrival (Schultze 1968).[12] Although defense contractors are privately owned firms, they contract with the government to provide the textbook example of a public good: national defense. Their primary market and largest customer is the federal government, and such firms are so heavily regulated (through cumbersome reporting and auditing requirements) that they "act" like the government.[13] In the case of cockpit accommodation, the Pentagon drafts the military specifications that contractors must follow; firms will be ineligible for contracts if their products do not meet these design guidelines.

Through procurement contracts, defense firms and their products stand on a politically determined claim to represent a generalized "public interest" (Johnston 1988). However, the notion of the public interest obscures the politically problematic question of how one calculates collective demand for such a policy. Because the standards for the political determination of the public needs are themselves contested, controversial technical decisions lead to multiple public interest claims and, in this case, well-publicized negotiation. The decision to change the JPATS sitting height requirement was a response to the demands of JPATS Cockpit Accommodation Working Group, retired women aviators and women's groups, and new political appointees receptive to women's issues.

However, a purely interest-based analysis of this situation lacks a theory of distributive politics. Industrial capitalist societies are not simply pluralist; they are stratified and differentiated into social groups with unequal status, power, and access to resources. Whether or not certain technological alterations are made depends not just upon interests of the relevant social groups, but on the power of each of these stakeholders. The "public interest" is likely to be captured by powerful interests while more marginal groups are likely to be excluded from formal political processes. In the case of cockpit accommodation, for example, the current and future servicewomen in whose name accommodation was sought had relatively little input in formulating

the design specifications. Participatory technological development may be more compatible with the system of public procurement, but this will not eliminate the barriers facing certain interest groups who lack the economic resources and political clout to be part of the official dialogue (Sclove 1995).

Within commercial divisions of contractors, technology is produced for private use and market exchange. In contrast to military divisions, commercial operations are excused from explicitly concerning themselves with "political" issues—such as equity—because such issues are cast in terms of private ownership prerogatives and impersonal market imperatives (Fraser 1989). Production and technical decisions assume an economic character and are cut off from competing obligations, no longer "embedded" in social and political relations (Meiksins Wood 1987). Although firms have the ability to adapt their technology on the drawing board, decisions about whether or not to accommodate women are cordoned off as private decisions based on the whims of management, the desires of particular customers, and the fear of litigation.

In government procurement, there are competing claims as to what are critical design considerations. Interest groups voice their concerns through a political process and, in the JPATS decision, were able to influence specifications which would allow more women pilots to fit the design criteria. In contrast, the private contractor need only attend to the singular (and often purely economic) claim of the customer airline's management through whom the voices of ultimate users, the pilots, are filtered.

Conclusion

The debates surrounding the accommodation of women in cockpit design demonstrate how gender and technology are mutually constructed. The design of the cockpit, on its face a gender-neutral issue, works to constitute men and women as essentially different social beings. Although men's and women's bodies tend to be physically distinct, technological specifications can translate that difference into an advantage for some and a disadvantage for others (Minow 1990; Cockburn 1985). It is not just that women are physically different than men, but that their difference carries with it barriers to career advancement and the stigma of abnormality.

In rectifying this problem, it is clear that both design criteria and the scope of regulation need to change. The entire science of ergonomics and anthropometrics is dedicated to defining the mean, median, or average-sized user who is treated as the norm from which all others "deviate." The statistical methods for creating such categories become embodied in the engineering

guidelines and specifications, effectively designing norms and gender biases into technology. In the same way that design specifications can exclude women, they can also be redrawn to include them—given the political momentum.

Regulatory processes can also provide effective avenues for change. Although the Pentagon is surely not a moral exemplar or the arbiter of the public interest, the state has done a more effective and extensive job of mandating accommodation for all operators than the market. In contrast, commercial divisions of aircraft-manufacturing firms that produce for commercial customers are subject only to the rules of private accountability that we associate with contract and labor law. In the end, private political-technical issues are regulated in the short-term by the courts—unless airline unions can bring these issues to the table when bargaining over the terms of their contracts.

Given its very potential for widespread effects on women's careers, design accommodation involves too many far-reaching equity issues to be left completely to private, profit-seeking agents (Fraser 1989; Olsen 1983). Technological accommodation in the private sector is a matter of public import, and airframe manufacturers should be held to the more comprehensive rules of public accountability that we associate with government contractors. Regulating the accommodation of a larger pool of pilots in the concept and design phase would ensure a more equitable outcome than relegating such issues to the "logic" of the market and the courts.

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 JPATS is the aircraft used by both the Navy and the Air Force to train its pilot candidates.

3. The FAA Statistics and Forecast Branch maintains information on the number of women pilots who have a current medical certificate and a pilot license. In 1993, 39,460 women held both the certificate and license out of a total of 665,069 pilots (Office of Aviation Policy, Plans and Management 1993). However these figures do not reflect the number of women actually employed as commercial pilots.

4. In the past, commercial pilots received their training in the military, whereas now the trend is to filter through private flight training schools.

5. Mary Katzenstein provided me with these insights. See also Enloe (1993, 208-14).

6. The Tailhook scandal refers to the annual Tailhooker's (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.

7. Asian customer airlines have raised the issue of accommodating smaller-statured men with American manufacturers. Interested in the potential for future profits generated by Asian markets, manufacturers like Boeing are becoming more responsive to such requests.

8. Many interview subjects noted that the European airlines tend, on average, to be more savvy about human-machine interface and ergonomics. For example, KLM possesses sophisticated human factors capabilities and is known for considering the "social" impacts of design. Whether one can attribute this sensitivity to the relative strength of unions or to the traditions of social democracy is open for debate.

9. See *Griggs v. Duke Power Co.* (1971). In this case, the Court invalidated minimum height, weight, and strength requirements that had a disproportionate effect on women and that could not be demonstrated to be job related.

10. Estimated costs associated with modifying the JPATS are $600 million, which include changes to cockpit layout, aircraft structure, flight control systems, ejection seats as well as the development of new anthropometric mannequins and building a new JPATS prototype (Department of Defense 1994).

11. Unless manufacturers can raise the prices they charge for their products, thereby netting more revenue, they are unlikely to undertake such investments given the current environment of competitive cost cutting.

12. *Nonexcludable* means that no one can be denied the good, even if they are not willing to pay for it. *Nonrival* means that an additional user can be satisfied without depleting the goods available to others.

13. See *Holodnak v. Avco Corporation, Inc.* (1975). In this case, the court determined that there were "sufficient links" between a defense contractor and the federal government to make the employer's action in dismissing an employee "state action" for the sake of pursuing a First Amendment claim. First Amendment claims may only be brought against public sector agents, so this case, in effect, demonstrates that defense contractors are a kind of public-private hybrid.

References

Aspin, L. 1993. *Policy on the assignment of women in the armed forces*. 28 April. Washington, D.C.: Department of Defense.

Binkin, M. 1993. *Who will fight the next war? The changing face of the American military*. Washington, D.C.: Brookings Institute.

Brownmiller, S. 1975. *Against our will: Men, women and rape*. New York: Simon & Schuster.

Brundage, W. 1993. The changing self-definitions of the military and women's occupational specializations. Paper presented at the workshop on "Institutional change and the U.S. military: The changing role of women," October, Cornell University.

Cockburn, C. 1985. The material of male power. In *The social shaping of technology*, edited by D. Mackenzie and J. Wajcman, 125-46. London: Open University Press.

Cooke, M., and A. Woolacott, eds. 1993. *Collateral damage: Gender and war*. Princeton, NJ: Princeton University Press.

Department of Defense. 1993. JPATS cockpit accommodation working group report. Unpublished report, 3 May.

Department of Defense. 1994. Studies of JPATS accommodation of women and the expansion of universal ejection seat capability. Unpublished report, 4 March.

Deutsch, J. 1992. Memorandum on JPATS cockpit accommodation working group report. Unpublished report, 2 December.

Dorn, E. 1993. Memorandum on JPATS cockpit accommodation working group report. Unpublished report, 19 October.

Enloe, C. 1983. *Does khaki become you? The militarization of women's lives*. Boston: South End Press.

———. 1993. *The morning after: Sexual politics and the end of the cold war*. Berkeley: University of California Press.

Fraser, N. 1989. *Unruly practices: Power, discourse and gender in contemporary social theory*. Minneapolis: University of Minnesota Press.

Gilmartin, P. 1992. Women pilots' performance in Desert Storm helps lift barriers in military, civilian market. *Aviation Week and Space Technology*, 13 January.

Griggs v. Duke Power Co., 401 U.S. 424 (1971).

Holodnak v. Avco Corporation, Inc., 514 F.2d 285 (2d Cir. 1975).

Johnston, P. 1988. Of public work and labor struggle. *Berkeley Journal of Sociology* 33:37-71.

Katzenstein, M. 1993. The formation of feminism in the military environment. Paper presented at the workshop on "Institutional change and the U.S. military: The changing role of women," October, Cornell University.

Key, E., E. Fleischer, and E. Gauthier. 1993. Women at sea: Design considerations. Paper presented at the Association of Scientists and Engineers, 30th Annual Technological Symposium, March, Houston, TX.

Law, J., and M. Callon. 1988. Engineering and sociology in the Military Aircraft Project: A network analysis of technological change. *Social Problems* 35:284-97.

MacKenzie, D. 1990. *Inventing accuracy*. Cambridge: MIT Press.

Markusen, A. 1985. *The economic and regional consequences of military innovation*. Berkeley, CA: Institute of Urban and Regional Development.

Markusen, A., and J. Yudken. 1992. *Dismantling the cold war economy*. New York: Basic Books.

McCormick, E., and M. Sanders. 1982. *Human factors in engineering and design*. New York: McGraw-Hill.

McDaniel, J. 1994. Strength capability for operating aircraft controls. In *Advances in industrial ergonomics and safety*, vol. 6, edited by E. Aghazadeh, 58-73. Bristol, PA: Taylor and Francis.

Meiksins Wood, E. 1987. The separation of the economic and the political in capitalism. *New Left Review* 127:64-94.

Melman, S. 1983. *Profits without production*. New York: Knopf.

Minow, M. 1990. *Making all the difference: Inclusion, exclusion and the American law*. Ithaca, NY: Cornell University Press.

Office of Aviation Policy, Plans and Management. 1993. *U.S. civil airmen statistics*. FAA APO-94-6. Washington, D.C.: Federal Aviation Administration.

Olsen, F. 1983. The family and the market: A study of ideology and legal reform. *Harvard Law Review* 96:1497-1578.

Pinch, T., and W. Bijker. 1984. The social construction of facts and artifacts. *Social Studies of Science* 14:399-441.

Reppy, J. 1993. New technologies in the gendered workplace. Paper presented at the workshop on "Institutional change and the U.S. military: The changing role of women," October, Cornell University.

Richman-Loo, N., and R. Weber. 1996. Gender and weapons design: Are military technologies biased against women? In *It's our military too! Women and the U.S. military*, edited by J. Stiehm, 136-155. Philadelphia: Temple University Press.

Roe Smith, M., ed. 1985. *Military enterprise and technological change*. Cambridge: MIT Press.

Schultze, C. 1968. *The politics and economics of public spending*. Washington, D.C.: Brookings Institution.

Sclove, R. 1995. *Democracy and technology*. New York: Guilford.

Sexton, G. 1988. Cockpit-crew systems design and integration. In *Human factors in aviation*, edited by E. Weiner and T. Nagle, 495-526. San Diego: Academic Press.

Stiehm, J. 1985. Women's biology and the U.S. military. In *Women, biology, and public policy*, edited by J. Stiehm, 205-34. Beverly Hills, CA: Sage.

Stone, K. 1990. The Railway Labor Act: Labor relations in the airlines. *Stanford Law Review* 42:1485-1549.

Wajcman, J. 1991. *Feminism confronts technology*. University Park, MD: Pennsylvania State University Press.

Weber, R. 1995. Accommodating difference: Gender and cockpit design in military and civilian aviation. *Transportation Research Record* 1480:51-6.

Wheelwright, J. 1992. "A brother in arms, a sister in peace": Contemporary issues of gender and military technology. In *Inventing women: Science, technology and gender*, edited by G. Kirkup and L. Smith Keller, 213-23. London: Open University Press.

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