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THE TECHNOLOGY QUESTION IN FEMINISM: A VIEW FROM FEMINIST TECHNOLOGY STUDIES

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Synopsis — Feminist research on technology tends to view technology either as neutral or as determining, drawing implications for women that are either overoptimistic or overpessimistic. By contrast, feminist scholarship within the field of technology studies, or feminist technology studies, is more ambivalent politically, and sees technology as socially constructed, or coproduced, alongside gender. This paper elaborates this framework by exploring various ways in which technology may be gendered, drawing in part on recent research on engineering. It focuses, in turn, on gender in and of technological artefacts; on the durability of masculine images of technology; on gender in the detail of technical knowledge and practice; and on the place of technology in (some) men's gender identities. This framework provides a more sound basis for understanding the ambivalence about technology which many women experience and, thus, for a praxis which steers a cyborgian course between uncritical endorsement and outright rejection of technology. © 2001 Elsevier Science Ltd. All rights reserved.

INTRODUCTION

I offer this paper in the belief that what we might, with apologies to Sandra Harding (1986), call "the technology question in feminism" has been generally neglected. While there exist several established streams of feminist scholarship on technologies, technology per se has been undertheorized in much of this literature, with serious implications for feminist praxis. I was to suggest that one stream—the feminist scholarship that has emerged within the field of technology studies, or *feminist technology studies*—provides a more nuanced and politically helpful framework for analyzing the relationship between technology and gender, which could usefully be generalized.

One obvious stream within feminist scholarship on technology concerns "women in technology" most commonly the question "why so few?" women in engineering. Despite nearly two decades of government and industry backed "women into engineering" campaigns, the numbers entering engineering are still derisory in most countries, even compared with those going into science. Quite apart from any discrimination or discouragement they may face, most girls and young women are voting with their feet: it does not occur to them to get into either craft or professional engineering; they just are not interested. The virtual failure of these initiatives indicates a failure to critically analyze the ways in which technology itself gets gendered in the eyes of would-be technologists. In particular, I believe the continued male dominance of engineering is due in large measure to the enduring symbolic association of masculinity and technology by which cultural images and representations of technology converge with prevailing images of masculinity and power (e.g., Balsamo, 1998; Burfoot, 1997; Caputi, 1988). Yet, consistent with the liberal feminist tradition, the "women in technology" literature and campaigns view technology as gender neutral and as unequivocally "a good thing," which women would enter into if only early socialization (e.g., to play

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with mechanical toys) and workplace structures (e.g., concerning childcare) were changed (Henwood, 1996).

Other streams of feminist scholarship on technology fall under the rubric of "women *and* technology," which focusses on specific technologies or technological arenas encountered by women, for example, in the workplace or in the course of reproduction. Understandably there is a larger body of work under this rubric, because vastly more women are "on the receiving end" of technologies than create them (Arnold & Faulkner, 1985). These encounters are often marked by extraordinary juxtapositions of positive and negative feelings about technologies. For example, women generally feel reassured by the diagnostic techniques used during pregnancy and believe that the existence of so much technology in hospitals means they are safer giving birth there than at home; while they often experience the technologies used to intervene in the birth itself as signalling danger and denying them control over their baby's delivery (Evans, 1985). Similarly, the opening up of the internet is greeted enthusiastically by some women as an exciting tool and a means of gaining technical confidence, while others want nothing to do with yet another "toy for the boys." It is notable that much of the available scholarship on women and technology fails to capture or explain women's ambivalence about technologies; it is characteristically either pessimistic or optimistic. In the latter case, there is a tendency to present technology as deterministically patriarchal (or capitalist) and to portray women as victims of men's technology (Berg, 1997, ch. 1). An example of this is provided by much of the early writing on new reproductive technologies, especially that coming from supporters of Finrage (e.g., Arditti, Duelli Klien, & Minden, 1984; Corea et al., 1985). Here, technology is seen as an inevitable extension of a male desire to control, and potentially eliminate, women's biological role in reproduction (Stanworth, 1987, p. 4; Wajcman, 1991; ch. 3). Similarly, a literal reading of some ecofeminist tracts (e.g., Merchant, 1980; Mies & Shiva, 1993) would dismiss the entire modernist technological project as being hopelessly bound up with a masculine world view that is detached from nature and from people. At the other extreme, where technology is seen as neutral, the converse occurs: overly optimistic political conclusions are drawn—as, for example, in the techno-enthusiasm of much cyberfeminism (e.g., Plant, 1997; Spender, 1995; criticized in Adam, 1997, 1998, pp. 166–181; Oldenziel, 1994).

By contrast, the view that emerges from feminist scholarship within the field of technology studies is self-consciously neither pessimistic nor optimistic (e.g., Berg, 1997, ch. 1). From early on, feminists in this tradition framed their concerns in terms of "*gender* and technology" rather than "women and technology," signalling (among other things) an insistence that both technology and gender be understood as socially shaped and so potentially reshapeable. The constructivist approach to technology (of which more below) is paradigmatic in social studies of technology and, crucially, challenges both technological determinism and any presumed neutrality of technology. Much of the "gender and technology" stream of research has focussed on the use and users of technologies in everyday life (e.g., Cockburn & Dilić, 1994; Cockburn & Ormrod, 1993; Lerman et al., 1997; Lie & Sørensen, 1996; Silverstone & Hirsch, 1992; Sørensen & Berg, 1991; *Technology and Culture*, 1997), providing a valuable corrective to the often exclusive focus on the design of radically new military or industrial technologies in mainstream technology studies (Cockburn, 1992; Faulkner, 1998). There is, nonetheless, important gender aware work beginning to be done specifically on men's relationships with technology, addressing both users and designers; hence, the newly emerging, related stream of research on "*men/masculinities* and technology" (e.g., Faulkner, 2000a; Lie, 1995, 1998; Lie & Sørensen, 1996, various chs; Lohan, 1998; Mellström, 1995; Oldenziel, 1999).

It is not my intention here to survey each of the streams of research flagged up above, or the various specific technologies that feminists have analyzed. Judy Wajcman's admirable review in *Feminism Confronts Technology* (Wajcman, 1991) remains an important source, and a recent paper by her (Wajcman, 2000) provides an updated commentary on past debates and present issues. My aim here is to elaborate and illustrate the broad framework developed by feminist technology studies. I do so in the belief that the constructivist approach to technology on which this framework builds provides a more realistic and useful basis for feminist action, precisely because it resonates with the ambivalence that women experience in encounters with technology. By the same token, I would argue, this approach helps to explain the tenacity of the equation between masculinity and technology while at the same time providing a basis for destabilizing that equation.

A useful way to approach the subject matter is to ask the question "how is technology gendered?" There are two fairly obvious aspects of this that feminism has taken on board, and so can be taken as read. First, it is primarily men who take the key decisions that shape technologies (albeit most men, like most women, are remote from these decisions). Second, men have generally had greater success than women in claiming skilled status, especially technical competence—including that mobilized in the construction, maintenance, marketing, and design of technologies (Cockburn, 1983a, 1985; Elson & Pearson, 1981; McNeil, 1987; Phillips & Taylor, 1980). The body of this paper explores some of the less obvious ways in which technology is gendered. It first explores gender "in and of" technological artifacts, arguing that even the nuts and bolts of technology justify a feminist gaze. Second, it identifies some of the masculine images technology that contribute to the continued male dominance of technological occupations even though these images are frequently not upheld in practice. Third, it looks in more detail at the often complex and contradictory gendering that takes place at the level of technical knowledge and practice—both symbolically and in terms of gender differences in "styles" of work. And fourth, the tenacity of the equation between masculinity and technology is further explored with reference to the place of technology in the gender identities of men who work and play with technology. The paper starts by outlining the basic theoretical framework that feminist technology studies broadly share, in particular the key tenet of the "coproduction of gender and technology," and it concludes by exploring tentatively the implications of a constructivist analysis of technology for a praxis which, in the spirit of Haraway's cyborg manifesto (Haraway, 1991), seeks to steer a course between outright endorsement or rejection of technology.

THEORETICAL UNDERPINNINGS: THE COPRODUCTION OF GENDER AND TECHNOLOGY

Early efforts to theorize gender-technology relations took differing stances about, crudely put, whether technology is male dominated because it demands some essentially masculine traits, or "simply" because technology is where the power is. On the more gender essentialist end of this debate, Brian Easlea (1981, 1983) argued that men gravitate to science and technology to compensate for a shared "womb envy"; ecofeminists emphasized men's emotional detachment from the natural world (e.g., Cox, 1992; Merchant, 1992); while others have drawn on psychoanalytical theory to explain the tenacious links between masculinity, abstraction and objectivity (Keller, 1990; Turkle & Papert, 1990). The alternative "power" position in the gender-technology debate appealed instead to an understanding of the social context within which particular gender constructions and particular technologies appear. Thus, Cynthia Cockburn demonstrated how groups of men have positioned themselves in key technological roles historically: metal working in feudal times, and machine tooling in industrial times (1985, ch. 1). And Judy Wajcman (1991, ch. 7) reminded us that modern technology is supported and directed by powerful institutions and interests.

Cockburn (1983a, 1985) and Wajcman (1991) between them laid two key foundations of feminist technology studies. First, in line with social studies of technology, they assumed a two-way mutually shaping relationship between gender and technology in which technology is both a source and consequence of gender relations and *vice versa*. Ruth Schwartz Cowan's seminal study of the relationship between changes in domestic technology and domestic labor since industrialization (Cowan, 1983) provides a sophisticated example of empirical work in this tradition. Second, in line with then current trends in feminist scholarship, Cockburn and Wajcman identified ways in which gender-technology relations are manifest not only in gender structures but also in gender symbols and identities. The value of using this simple triad for analyzing gender relations was of course first spelt out by Sandra Harding (1986, ch. 1) and Joan Scott (1988), and continues to be acknowledged by many feminist scholars of technology (e.g., Berg, 1997; Faulkner, 2000a; Lerman, Mohun, & Oldenziel, 1997). The framework reminds us that there is more to the male dominance of technology than power. It also obliges us to explore much more closely the distinct-but-related links between structures, symbols, and identities in the gender-technology relation—as Meret Lie (1998) and Anne-Jorunn Berg (1997) have begun to do.

The wider links between gender and technology, in structures, symbols, and identities, have long been acknowledged by feminists. Because both modern technology and hegemonic masculinity (Connell, 1987) are historically associated with industrial capitalism, they are linked symbolically by themes of control and domination. Achieving control and domination over nature was a central plank in the Baconian project (Easlea, 1981; Merchant, 1980; Noble, 1991), and the "mastery of nature" remains a powerful emblem of technology (and science)—both within engineering (e.g., Florman, 1976, pp. 121–126) and in wider culture (e.g., Caputi, 1988). In this sense, technology is understood as a "masculine culture" (Wajcman, 1991, ch. 7).

During the 1990s, however, writers in the feminist technology studies tradition became increasingly sensitized to the dangers of essentializing either gender or technology by such formulations (e.g., Grint & Gill, 1995, ch. 1; Grint & Woolgar, 1995). Accordingly, the mutual shaping of gender and technology framework has been recast in a poststructural trope in which gender and technology are seen as *coproduced* (e.g., Berg, 1997, ch. 1; Lerman et al, 1997). Here a parallel is drawn between the social construction of gender and the social construction of technology, in which each are seen as performed and processual in character, rather than given and unchanging. The social construction of gender does not need rehearsing in a feminist journal, but it is necessary to outline some key tenets and concepts from constructivist technology studies—precisely, because, as this paper argues, this framework warrants greater familiarity and usage in wider feminist scholarship.

The starting point of social studies of technology is a rejection of technological determinism, in particular a rejection of the views (i) that technologies develop in predetermined directions, and (ii) that technologies determine social change (MacKenzie & Wajcman, 1999, ch. 1). An important step was taken in constructivist technology studies with the adoption of Thomas Hughes' notion of the *sociotechnical* (1986). The unusual step of creating a composite, nonhyphenated word is intended to convey that technology is never "just" technical or "just" social. Rather, the relationship between technology and society is a densely interactive *seamless web* (Hughes, 1986). This means that the expertise and choices involved in designing and developing new technologies are necessarily *heterogeneous* (Law, 1987). Thomas Edison's success with the electric light bulb, for example, rested not only on technical inventiveness about filaments, but also on the economic calculations about what properties the filament needed to have for electric lighting to compete with gas lighting, and on his having the entrepreneurial and political acumen to mobilize financiers and city authorities to back the establishment of the requisite infrastructure (Hughes, 1983). Heterogeneity also means that artifacts are understood as being thoroughly part of the social fabric: so electric lighting is a sociotechnical system encompassing a myriad conventions in social organization as well as the complexly configured artifacts of power generation, distribution, and use (Hughes, 1983). Bruno Latour has argued that artifacts need to be viewed as *nonhuman actors* (Latour, 1992) which are *inscripted* (Akrich, 1992) to have certain material (sociotechnical) "effects," self-closing fire doors being his classic example.

In a very real sense, constructivist technology studies argue, those who design technologies are by the same stroke *designing society* (Bijker & Law, 1992; Latour, 1988), and for this reason, sociology cannot afford to ignore what Latour calls the "missing masses" of "mundane artifacts" (1992). But the process of designing societies and technologies is not straightforward, for at least two good reasons. First, in the development of a new technology there is considerable *interpretative flexibility* (and contests) about the meaning of the putative artifact and, thus, its eventual shape (Pinch & Bijker, 1984). For instance, there were numerous, bizarre configurations of frame, wheels, pedals, and seats before the modern bicycle emerged in its now familiar shape. These reflected in part the divergent interests of different users: for some the bicycle represented a potentially dangerous but daring sport; for others, it represented a safe means of getting around (Pinch & Bijker, 1984). Second, artifacts do not always simply reflect the intentions of their designers or even the interests of their paymasters. They can have *unintended consequences*—as, for example, in the way that Victorian buildings exclude wheelchair users. And there can be considerable scope for interpretative flexibility in the context of *use* as well as design (as this paper demonstrates below).

The poststructural turn is palpable in constructivist technology studies as elsewhere, prompting some to argue that the more action oriented methodologies and frameworks too often lose sight of power (e.g., Williams & Russell, 1989; Winner, 1993). Similarly, within feminist technology studies, there is a tension between, on the one hand, the structuralist emphasis on the historical roots and durability of equations between masculinity and technology and, on the other hand, the antiessentialist refusal to see either technology or men as necessarily about control and domination (Grint & Gill, 1995; *Science, Technology, & Human Values*, 1995). My own response is to embrace this tension: to adopt some of the principles of poststructuralism—in particular, its emphasis on complexity and contingency, and on multiple, decentered agencies with no singular lines of causation—without losing sight of "power" altogether: like Cockburn (1992), I believe that the perception of power as "capacity" embedded in actor network approaches just misses the point that many women (and men) experience power as domination. This position is consistent with a common juxtaposition in feminist technology studies (and familiar in feminist scholarship more widely) of a refusal to abandon gender as an analytical category (e.g., Cockburn, 1992) and an insistence on the possibility of change and diversity in gender-technology relations (e.g., Berg, 1997).

TECHNOLOGICAL ARTIFACTS AS GENDERED

Social constructivism holds within it the possibility that technological artifacts could be other: once their social basis has been deconstructed, they can be reconstructed along different assumptions and priorities (Bijker & Law, 1992; Bijker, Hughes, & Pinch, 1988; MacKenzie & Wajcman, 1999). But it is also acknowledged that in practice many sociotechnical arrangements are quite stable, irrespective of the (in principle) potential for fluidity. The field of technology studies has produced divergent evidence on the malleability or otherwise of specific technological artifacts, with some appearing almost entirely tool-like, devoid of politics, while others seem to be quite literally instruments of oppression (e.g., Winner, 1999). The question this raises here is *how much, and in what ways, are technological artifacts gendered?*

It is useful to distinguish between gender *in* technology and gender *of* technology. In the former case, gender relations are both *embodied* in and constructed or reinforced *by* artifacts to yield a very material form of the mutual shaping of gender and technology. In the latter, the gendering of artifacts is more *by association* than by material embodiment. In practice, various forms of gendering can be identified between these two scenarios—as I now demonstrate.

One aspect of the gendering by association lies is the symbolism that attaches to technology. In the language of "male" and "female" parts used in all electromechanical technologies, for example, the mutual shaping of gender symbols and technological discourses is quite apparent: the use of this sexual metaphor to label technological artifacts both reflects and reinforces the message that heterosexuality is the norm; it acts to "naturalize" heterosexual relations.

Another aspect of gendering by association is that the technologies we encounter are often strongly gendered in terms of prevailing divisions of labor. Thus, of the technologies present in the modern household, only a small number are used equally by women and men; those used in the routine tasks of cleaning and cooking are more commonly used by women and girls, while those used in the nonroutine tasks of home maintenance and gardening, plus the more "high-tech" music systems, are more commonly used by men (Gershuny, 1982). Similarly, in a rare study of gender symbols in computers, the late Julia Shaffner (1993) found that some computer scientists saw the number key pad on the computer as masculine, because they associated it with mathematics, which more men than women do, while others saw it as feminine, because they associated it with data entry, which more women than men do.

Often, such gendered associations are not merely "added on" by users "after the event." Designers themselves make gendered assumptions about the user, assumptions that can be "designed in" to the artefact. This moves us closer to gender *in* artifacts, as is nicely illustrated in Cynthia Cockburn and Susan Ormrod's (1993; Ormrod, 1994) excellent study of the microwave. Initially designed and marketed as a "brown good"—for the heating of prepared meals—to appeal to single men who were assumed to be more interested in and knowledgeable about hi-fi equipment than cooking, this product was then redesigned as a "white good"—with more complex "combi" cooking facilities—and sold to family households in which it was assumed that the woman does most of the cooking, and is both skilled and interested in cooking. Again, the mutual shaping of gender and technology is evident: features designed in to artifacts tailored specifically for women or men users tend to reflect and reinforce gender stereotypes, which in turn, play in to design choices.

But while the gendering described above may encourage certain gendering of use, there is nothing materially determining going on here: women and men use both types of microwaves. A more embodied form of gendering is clearly going on in the case of those medical technologies of reproduction specifically designed for either women's or men's bodies, and many of these technologies clearly do have material consequences for gender relations: the obstetric forceps, for example, were a material manifestation historically of the medical profession's interests in gaining control over childbirth (Versluysen, 1981). Similarly, diagnostic technologies like ultrasound scanning used during pregnancy have encouraged a tendency for pregnant women to be seen as "walking wombs" (Oakley, 1987) because they reduce doctors' reliance on women's knowledge (e.g., about when they conceived).

Gender can also be embodied *in* artifacts in the case of industrial technology designed to automate the labor process where the gender segregation of labor is extreme.[1] Cockburn's seminal study of technical change and compositing work in the print industry provides a now classic example (1983a). When the industry began to mechanize typesetting, with the introduction of Linotype technology in the 1880s, the Monotype Corporation introduced a machine for the book trade with the aim of helping employers to break the craft strength of the male compositors' union and so reduce labor costs. It sought to do this by splitting the tasks of keyboarding and casting into different machines, and by using a QWERTY keyboard to facilitate the entry of women into the former (typewriting had by then become feminized). Because the Linotype machine did both tasks, and used a keyboard that was completely different from that of the typewriter, the compositors' trade union supported *its* technological development and blocked the diffusion of the Monotype. By so doing, they effectively blocked a possible avenue for women to enter a high-status, well-paid area of work.

In cases like this one the gendering of the artefact is more than symbolic or contextual; its very design rules out malleability. By contrast, some technologies are barely gendered at all: it is hard to "see" gender in the cassette tape machine, for instance, although we may readily impute gender in the words or music that the machine is used to play. As Anne-Jorunn Berg and Merete Lie (1995; Berg, 1994) among others stress, many artifacts may be *reinterpreted*, or subject to multiple constructions, by users long after they have left the factory gates; they are more tool-like. The telephone is a classic illustration: first introduced for domestic use on the assumption that businessmen would find it useful to call colleagues from the home, it was rapidly appropriated (or "domesticated") by the wives of businessmen as an adjunct to their social and family life (Frissen, 1994).

For me it is important to explore the various ways in which artifacts are gendered, because it serves to underline the otherwise (to many) improbable point that even the "nuts and bolts" of technology warrant a feminist gaze. But the exercise also warns against any temptation to simplistic theorising since artifacts are clearly gendered *to varying degrees*. On the one hand, I have shown that while some artifacts do manifest the interests of (some) men in a material way, most are gendered by association, symbolically rather than materially, and many are not obviously gendered at all. On the other hand, I believe that the constructivist emphasis on reinterpretation may be overoptimistic, even idealistic: prevailing social relations (especially gender relations) are often far harder to change than material technologies (Soper, 1995). So, while we may conclude *in principle* that technology can aid female empowerment, appropriating individual technologies is unlikely to be effective in practice if we ignore the wider gender contexts within which they are designed and used.

MASCULINE IMAGES OF TECHNOLOGY

The symbolic gendering of technology extends beyond the artifactual, but may still have material consequences. In this section, I highlight some aspects of the association between masculinity and technology—an association that operates largely at the level of the *image* technology holds for outsiders, and that I argue contributes to the continued male dominance of many technological occupations.

Within the masculinity-technology association, one can discern a series of highly gendered dichotomies (Faulkner, 2000b). Most obvious of these is the distinction between being people-focussed and machine-focussed—one version of the sociological distinction between feminine expressiveness and masculine instrumentalism. Sherry Turkle (1988) shows that women starting out in computing are often reticent about computing, because they see hobbyist hackers as the only model for intimacy with computers, and so many hackers appear to eschew or be incapable of human intimacy. Similarly, Tove Håpnes and Bente Rasmussen demonstrate that a central reason for the declining intake of young women into computer science in Norway is girls' rejection of the "nerd" image of computer hackers (Håpnes & Rasmussen, 1991). It seems that for a woman to opt to work so closely with technology is potentially to reject any meaningful engagement in the social world and so face "gender inauthenticity" (Cockburn, 1983b; Keller, 1987).

This reveals a key feature of the people-technology dichotomy, namely that it is assumed to be mutually exclusive. Yet, most women routinely interact with people *and* technologies; some even develop strong emotional attachments to artifacts they use a lot, be it a washing machine or a pager (Berg, 1997, chs. 4 and 5). As feminists scholars of technology have long argued, however, women's everyday encounters with technological artifacts are rarely recognized as such (Berg & Lie, 1995). Computers aside, our most common cultural images of technology—industrial plants, space rockets, weapon systems, and so on—are large technological systems associated with powerful institutions. Here we meet a second interesting dichotomy, in this case one that categorizes artifacts symbolically and is implicitly rather than explicitly gendered. "Hard" technology is inert and powerful like the examples above; this is *real* technology. "Soft" technology is smaller scale, like kitchen appliances, or more organic, like drugs; most people do not readily identify such products as "technology." So the world of technology is made to feel remote and overwhelmingly powerful because the hard–soft dualism *factors out* those other technologies that we all meet on a daily basis, and can, in some sense, "relate to."

The hard–soft dichotomy also extend to styles of thought in technology (Edwards, 1996, pp. 167–72), because the association of engineering with scientific methods brings with it longstanding gender dualisms: on the masculine side of those dualisms we have an objectivist rationality associated with emotional detachment and with abstract theoretical (especially mathematical) and reductionist approaches to problem solving. On the feminine side we have a more subjective rationality associated with emotional connectedness and with concrete, empirical, and holistic approaches to problem solving. As we will see in the next section, abstract "styles" of thinking and working are often associated more with men and concrete ones with women, yet both sides of the concrete–abstract dualism are required within engineering and computing practice.

I return to these familiar dualisms for the same reason Evelyn Fox Keller does in relation to science (1990): they are widely held as truths by technical and nontechnical people, women and men, alike. This was very clearly illustrated in the 1993 Special Issue of *Science* (*Science*, 1993) on Women in Science, where the testimony of several scientists was mobilized to support the claim that women bring a different "style" to science (Barinaga, 1993; Morell, 1993). The fact that popular images of both science and technology are strongly associated with the masculine side of these dualisms must be one of the reasons why, in a deeply gender divided world, most girls and women do not even consider a career in engineering.

This assertion is supported by evidence from studies of technology education in UK schools. Early differences in interests and role playing developed outside school shape how girls and boys respond to, and are interpreted as responding to, technology in school. For example, girls are more likely than boys to feel confident about, and to succeed in, working with tables of data concerning health, reproduction, or domestic situations, but anticipate failure—"I don't know anything about that"—when faced with tables of data on machinery, building sites, or cars (Murphy, 1990). The reverse holds for most boys: the task is the same but the content is gendered. Girls are usually less confident than boys in handling "real" technology—and this extends to the use of all sorts of equipment in school, which boys tend to monopolize. The greater people-centeredness of most girls is also reflected in *how* they approach technical tasks. Recent surveys undertaken in UK schools reveal that teenage girls in design and technology classes are more likely than boys to "identify the issues that underlie tasks in empathising with users and evaluating products and systems in terms of how well they might perform for the user," whereas boys are more likely to approach technical tasks in isolation and judge the context to be irrelevant (Kimbell, Stables, & Green, 1996, p. 94; Murphy, 1990). For example, in a group of 13–15-year-old pupils asked which of two materials would make the warmest jacket for a person stranded on a cold windy mountainside, many girls but none of the boys took context into account—by cutting out prototype jackets to see how appropriate the materials were for making a jacket, and by dipping them into water to see how effective their insulating properties would be if it rained (Murphy 1990).

This is an astounding finding: it seems that girls demonstrate greater potential in precisely those heterogeneous approaches so necessary to success in technological design. Yet their different learning styles were read by teachers as off task and irrelevant (Murphy, 1990). Similarly, in their study on the acquisition of programming skills by schools and college students, Sherry Turkle and Seymour Papert (1990) found that girls and women tend to adopt an interactive or relational "bricolage" approach, while boys and men tend to adopt a formal and hierarchical "planning" approach. Both approaches "work," yet the bricoleurs found themselves actively discouraged by their teachers, forced to pursue this approach surreptitiously or unlearn it or give up on computing. Such findings indicate aspects of the exclusion of would be female technologists rarely grasped by equal opportunity campaigns.

Of course, many of the ways of thinking and doing, which we stereotypically deem feminine, are useful if not essential in technical work: linguistic abilities in computer programming, for instance. And plenty of women now do jobs that are extremely technical, just as plenty of men are technically incompetent. In short, there are huge mismatches between the image and practice of technology with respect to gender. This crucial point is often missed. Yet I believe it obliges us to look more closely at the relationship between the continued male dominance of engineering and masculine images of technology, and at how these images are sustained.

GENDER SYMBOLS IN TECHNICAL KNOWLEDGE AND PRACTICE

The mismatch between image and practice highlighted here also invites us to bring a gender gaze to the "black box" of technical knowledge and practice—to investigate any symbolic gendering of technological work, and any gender differences in "styles" of technological work. There is a crying need for detailed empirical work in this area. However, we do have a small number of studies, which together appear to suggest that the gendering that takes place at this level is both more complex than conventionally assumed and highly contradictory. I illustrate this briefly in relation to engineering (Faulkner, 2000a, 2000b).

A useful way into this complexity is to focus on some of the dichotomous ways in which engineering work is often categorized. The most obvious and perhaps pivotal of these is the distinction between the manual labor of the craft or technician engineer,[2] who works directly on the artifact in a greasy workshop, and the mental labor of the professional (graduate) engineers, who frequently works remotely from the artifact (via a computer) in an almost clinically clean office. As Wajcman argues (1991, ch. 6), these two versions of masculinity are essentially class based, and embody the often gendered dualism of mind–body. But the distinction is also reproduced *within* professional engineering practice because it nevertheless involves hands-on "tinkering" work as well as mathematical analysis. So, the dualism inherited from science, which labels concrete, empirical approaches as feminine, is at odds with the importance of hands-on work in both technician and professional engineering. Similar juxtapositions of apparently dualistic concrete and abstract approaches are also found in computing. Software developers often draw a distinction between top down, planning approaches to programming and more "bottom up" approaches involving trial and error, which hackers excel at and which are apparently favored by women students (Turkle & Papert, 1990). In practice, most programmers nonetheless use judicious mixtures of concrete and abstract approaches (Håpnes, 1996).

Within professional engineering education (at least until recently in the United States), higher status and credit attaches to the more mathematical and abstract analytical work and less to hands-on concrete work—even though it is widely recognized that those who become the best engineers are often not those who perform the best academically (Hacker, 1989, ch. 3). As the late Sally Hacker experienced, engineering education is characterized by seemingly endless and repetitive drills of mathematically based, analytical problem solving (1989, ch. 3). In a very interesting passage, Louis Bucciarelli deconstructs a typical university engineering problem to demonstrate just how much of this complexity has to be pared away: "The student must learn to perceive the world of mechanisms and machinery as embodying mathematical and physical principle alone, must in effect learn to *not* see what is there but irrelevant . . . Reductionism is the lesson" (1994, p. 108, emphasis original). The recourse to mathematics in such exercises acts to reinforce an ideology of emotional detachment, which stands in stark contrast to the emotionally laden dramas that ethnologists (Bucciarelli, 1994; Mellström, 1995) and journalists (Kidder, 1981) have observed unfolding in engineering practice. Such exercises also act to exclude much "social" information, which is vital to the design and implementation of new technologies.

This brings us to the technology-society dualism. As noted earlier, sociologists and historians of technology have long noted that both sides of this dualism are present in the design of new technologies, that engineers must take a holistic view and integrate heterogeneous social and technical elements if artifacts are to "work" and meet a "real" need (e.g., Law, 1987; Sørensen & Levold, 1992). Indeed, technologists typically celebrate the rather heroic and generally masculine model of the heterogeneous engineer provided by the likes of Thomas Edison (Hughes, 1983).[3] In practice, however, this model is increasingly at odds with the present-day reality of a fragmented labor process in engineering (Constant, 1984; Sørensen, 1997), in which most engineers occupy specialist roles, where reductionism is acceptable, while only a few ever occupy heterogeneous roles, where holism is necessary and "the social" cannot be deemed irrelevant.

Stereotypically, greater feminine expressiveness would seem to make women engineers good candidates for heterogeneous roles. This is consistent with the evidence discussed in the previous section, that UK school girls appear to be good at addressing the context of design. It is also consistent with Martha Trescott's historical studies, which suggest that early women pioneers in the profession tended to bring a more holistic approach to problem solving in engineering (Trescott, 1984). Accordingly, women into technology campaigns increasingly play up the social aspects of engineering and computing in order to stress the particular contribution women might make. Such discourses can be criticized for being politically conservative: they leave intact the equations between masculinity and technology, and between femininity and expressiveness. They also eclipse considerations of power. In practice, the technical–social dichotomy gets gendered in contradictory ways with women gravitating to the more heterogeneous roles, such as in marketing or management, in some organizational settings and men doing so in others. The general picture which emerges, in this area as in others, is that men occupy those roles that receive higher status irrespective of any putative gender labelling of the skills involved (McIlwee & Robinson, 1992; Woodfield, 2000).

As this evidence implies, the question of whether women and men bring, or might bring, different styles to engineering is very contested (Faulkner, 2000a), and must remain open. This does not have to be an essentialist thing. It is likely that in principle engineering could be approached in many different ways, but that any such epistemological pluralism (Turkle & Papert, 1990) is suppressed in practice as a result of pressures to conform (Sørensen & Berg, 1987), both in the education system and in the workplace. Indeed, women engineers may well experience greater normative pressures than their male colleagues because of the struggle to be seen as "as good as" the men (Carter & Kirkup, 1990; Cockburn, 1983b; Hacker, 1989, ch. 3; Kvande, 1999).

Returning to the bigger picture, it will be clear that many dualistic epistemologies found in engineering practice are gendered in contradictory ways. There is nothing inherently gendered about the distinctions addressed here; nor I suspect are they intrinsic to technical knowledge and practice. For this reason, it might be worth exploring further why dichotomous or dualistic thinking appears so endemic to technology, and whether this relates at all to gender (Faulkner, 2000b). Gender is of course conceived of in dichotomous terms—not only because of the obvious link with sex (as in femaleness and maleness) but also because heterosexuality is usually posited ideologically on an attraction of gendered opposites. I agree with Flis Henwood (1993) that heterosexism is an under researched theme in the gendering of technology, and believe it may provide at least partial answers.

GENDER IDENTITY IN RELATION TO TECHNOLOGY

Finally, technology is gendered in relation to individual gender identities—how we go about being men and women. Here, I elaborate an argument in relation to professional engineering, which I suspect holds in broad terms for all male-dominated areas of technical work including those where manual rather than mental prowess is privileged. I argue that engineers' pleasure in technology, their close identification with technology, and their pride in technical competence are all crucial elements in the individual identities and shared culture of engineers. They provide some solace and reward to engineers whose everyday work and lives often offer only limited excitement or power. And they cement a fraternity that effectively excludes women engineers from important informal networks.

The "glint in the eyes" of engineers is evident to all who have cared to look. In *The existential pleasures of engineering*, Samuel Florman (1976) extols at length the sensual absorption, spiritual connection, emotional comfort, and aesthetic pleasures to be found in engineers' intimacy with technical artifacts. As a civil engineer, he described a "yearning for immensity" inspired by nature, an existential impulse for the "vanity of pyramids or dams" (1976, pp. 122, 126). Similarly, Sally Hacker both witnessed and experienced the sensual, even erotic, pleasures to be had in making things work. She perceived that part of the pleasure of engineering is a pleasure in domination and control—over workers as well as the natural world—which she saw as echoing prominent themes in present-day eroticism (1989, ch. 3; 1990, ch. 9).

The connection with eroticism is frequently hinted at by feminists, not least because it is overwhelming in the language of potency and birth that surrounds military technology (Easlea, 1983). In her very thoughtful and illuminating ethnography of defense intellectuals, Carol Cohn (1986) suggests that this language does not necessarily reflect individual motivations; rather, it may function to tame or make tenable "thinking the unthinkable"—of nuclear annihilation. Eroticism surrounding technology is nonetheless an important theme in cultural studies of technology (e.g., Balsamo, 1998; Burfoot, 1997), and warrants further investigation. However, I want to pick up here an argument suggested by Hacker, that the fun engineers have the technology is a *compensation* for contributing to larger systems of dominance and control—an especially important "reward" when so many engineers occupy fragmented roles in the labor process, and when other sources of job satisfaction may be limited (1989, ch. 3). I see a resonance with Florman's (1976) rhetoric about dams: the power of the technology symbolically extends engineers' limited sense of strength or potency.

As Downey and Lucena note, "engineers routinely feel powerless themselves but are viewed as highly empowered by outsiders" (Downey & Lucena, 1995, p. 187). This is reflected in engineers' frequent complaints about the imposition of business perspectives and priorities, which are seen as "as threatening the technical core of their professional identity" (Mellström, 1995, p. 54). On a wider stage, the men who take most pleasure in technology are often far less powerful than engineers—hackers and other technical hobbyists are obvious examples. Maureen McNeil asks, "couldn't the obsessional knowledge of some working class lads who are car buffs, or some of the avid readers of mechanics or computer magazines, be interpreted as evidence of impotence?" (1987, p. 194). Flis Henwood responds that in such cases technology offers a *symbolic promise* of power, as well as the potential to compensate materially for their relative lack of class power by acquiring technical expertise and so "strengthening their gender power" (1993, p. 41). Perhaps another kind of symbolic power promised by engineering is power over wayward emotions. The drills of mathematical problem solving in engineering education described earlier might be seen as encouraging a split between emotionality and rationality in which abstraction offers the promise of control or mastery over emotions (Hacker, 1990, ch. 4). Paul Edwards suggests that the "microworlds" of computer programming offer a retreat from "unwanted emotional complexity . . . For men, to whom power is an icon of identity and an index of success, a microworld can become a challenging arena for an adult quest for power and control" (1996, p. 172). It is, of course, commonplace to find at least some engineers and computer specialists who seek refuge from human relationships in technology (e.g., Håpnes, 1996; Mellström, 1995).

Engineers both identify with technology and share pleasure and pride in their technical competence. Judith McIlwee and Gregg Robinson comment on the basis of interviewing U.S. engineers;

> The culture of engineering involves a preoccupation with tinkering that goes beyond the requirements of the job. Vocation becomes avocation, and, in turn, devotion. It is not enough to be competent in the hands-on aspects of engineering: one should be obsessed with them. It is not enough to know the difference between a piston and a rod: one should take obvious joy in this knowledge. The engineers must be ready not only to engage in technical exchanges during work periods, but interested in participating in them during breaks as well. To be seen as a competent engineer means throwing one's self into these rituals of tinkering (1992, p. 139).

Ethnographies reveals that engineer's humor typically celebrates their technical prowess and ridicules the lack of it in others (Hacker, 1990, ch. 4; Mellström, 1995, ch. 5). By this stroke, technical prowess is what defines them as engineers *and* what gives them a sense of power.

The pleasures men take in technology are a very important factor in the continued male dominance of technical work. Boys are far more likely than girls to engage in technical hobbies (Haddon, 1990; Kleif, 1999). Frequently, such interests strengthen during adolescence—in the classic case of taking cars apart, technology provides a rare focus for bonding between fathers and sons—with the result that engineering is a "self-evident" career choice for most male engineers (1995, ch. 7). As Ulf Mellström observed among Swedish engineers, ritualistic displays of hands-on technical competence are a homosocial enactment and "engineering practice tends to reproduce patterns of homosociality" (Mellström 1995, p. 152). The women engineers studied by McIlwee and Robinson did not share their male colleagues' obsession; they had other topics of conversations and sources of joy. In organizations and disciplines where engineers enjoy high status, they benefit from the "power to create a workstyle comfortable to them as men" and (by the same token) alien to women. The centrality of technology is stressed, and aggressive displays of competence are the accepted means of landing the more interesting assignments and jobs (McIlwee & Robinson, 1992, p. 138 and ch. 1). In this situation, it is hardly surprising that women engineers tend to drop out or to lose out in career terms: they never really "belong to the club," and it is hardly surprising that the entry of women is (still) greeted with hostility by many engineers: it challenges what it means to be a man (Murray, 1993) and, perhaps, it threatens to spoil their fun (Faulkner, 2000a).

SUMMARY AND TENTATIVE CONCLUSIONS

Cynthia Cockburn once argued that "technology itself cannot be fully understood without reference to gender" (1992, p. 32). This paper has elaborated Cockburn's claim in terms of the question "how is technology gendered?" We may summarize its conclusions as follows:

1. technology is gendered because *key specialist actors*—especially in the design of new

technological artifacts and systems—*are predominantly men*
2. there are strong *gender divisions of labor around technology*, based in part on an equation between masculinity and technical skill
3. *technological artifacts can be gendered*, both materially and symbolically, although there often remains considerable interpretative flexibility in their use
4. *cultural images of technology are strongly associated with hegemonic masculinity*, although there is a huge mismatch between image and practice.
5. *the very detail of technical knowledge and practice is gendered*, albeit in complex and contradictory ways
6. *styles of technical work may be gendered* somewhat, although there are strong normative pressures to conform
7. technology is an important element in the *gender identities of men who work and play with technologies*

The constructivist framework elaborated here defies the kind of simplistic treatments in which technology is seen as either unproblematically a product of male interests, or as neutral. It obliges us to view gender *as an integral part* of the social shaping of technology. It, thus, challenges any presumed neutrality of technology by focusing on how gender might enter or be expressed in the very design of the technologies women encounter. And it challenges determinist views of technology by acknowledging that individual technologies are subject to considerable interpetative flexibility in both use and design. Even more profoundly, the notion of the "sociotechnical" in technology studies captures the sense that technology and society are mutually constituting—hence, the coproduction of gender and technology.

The symmetry of this analytical framework suggest that just as one cannot understand technology without reference to gender, so one cannot understand gender without reference to technology. This I would suggest is the huge challenge of the technology question in feminism. There are at least three important implications of this challenge for feminism.

First, I maintain that technology is—both materially and symbolically—a huge, often critical, element of hegemonic masculinity. In this context, the undertheorization of technology in feminist scholarship, and its virtual neglect in research on men and masculinities, are surprising and serious lacunae. I would suggest that further research on the durability of the technology–masculinity equation, and on the diverse interactions between technolog*ies* and masculinit*ies* found in practice, would both deepen our understanding about gender identities and power relations more broadly, and help to destabilize that equation.

Second, I believe that the notion of the sociotechnical, especially Latour's insistence that artifacts are nonhuman actors integral to the social fabric (1992), provide valuable tools for feminist scholarship more broadly. Although they come from very different political traditions, there is a resonance between this aspect of the sociotechnical and Haraway's conceptualization of our cyborg-like existence (1991). In our growing understanding of the body, for example, the notion of the sociotechnical allows us to hold on the materiality of the embodied body as we also acknowledge its constructedness and discursive elements. Recent work of Alison Adam (1998) and Anne Balsamo (1998) builds on this approach (without "naming" it sociotechnical) to good effect.

Third, moving from scholarship to praxis, the challenge of the technology question in feminism means that *we cannot transform gender relations without engaging in technology*. This is not a straightforward matter—precisely because the ambivalence evident in feminist analyses of technology and in women's encounters with technology is a recurring theme in the area of praxis also. For individual women, the effect of the felt ambivalence about technology is often either immobilising or polarising. And in collective feminist responses to and strategies for technology, two ends of a spectrum can be discerned. At one end, we see liberal feminist campaigns to get more women into engineering in which the current shape of modern technology is broadly endorsed. At the other end, we see the rejection of the whole technological project implicitly (if not explicitly) suggested by ecofeminism, and apparently reflected in the armies of girls and women who vote with their feet away from any career in technology. In the spirit of Donna Haraway's cyborg manifesto (1991), I believe the tension between optimism and pessimism that necessarily characterizes feminist technology studies obliges feminist activists to steer a difficult course somewhere in between complete rejection and uncritical endorsement of technology. I, therefore, finish by exploring briefly the possibilities for feminist action that have emerged to date.

FEMINIST STRATEGIES FOR TECHNOLOGY

One available tactic in the terrain between rejection and endorsement is to look for non-threatening ways of enabling women to increase their technical competence so that they are less reliant on men's expertise. The "mend your own car" and IT classes, which became popular in the 1980s, sought to challenge stereotyped equations of men and skill, while women's self-help health groups sought to develop and share alternatives to medical knowledge and practices. Another set of tactics has been for women to organize as active consumers of technologies—from the women's peace camp at Greenham Common against the siting of nuclear 'Cruise' missiles, to the ground swell of outrage about the technologized management of hospital births in the late 1970s and early 1980s in the United Kingdom (Boyd & Sellers, 1982), which catalyzed the introduction of birth plans and other "informed choice" procedures in the National Health Service.

There are inevitable limitations to women's likely impact as consumers of technology, however skilled or informed, because most women are very remote from the design process. The gains are thus invariably small-scale improvements, because "choice" is always constrained by what technologies are currently in use. The general problem here has been dubbed the "Collingridge dilemma": the consequences of new technologies can not always be predicted, and by the time it becomes apparent that something is wrong with a technology, both its artifactual form and the social interests surrounding it, have become so entrenched that they represent major barriers to change (Collingridge & Reeve, 1986). The conclusion for feminists has to be that we need to develop strategies to intervene in the process of designing new technologies *as well as* in the context of use.

Some interesting experiments have taken place along these lines: for example, attempts to involve women office workers in "human-centered" systems design (Green, Owen, & Pain, 1993). The evidence suggests that such initiatives rarely allow for more radical changes in either the organization of work or technological design. Janine Morgall (1993) suggests an approach that might prove more radical: critical feminist technology assessment seeks to extend existing technology assessment procedures[4] by, first, giving voice to the full range of interested groups in technological design and, second, starting from a critical debate about what and whose needs are to be met, rather than from existing technologies.

Taken together, these tactics amount to a strategy for democratising technology from the "outside in." No one, certainly not me, is suggesting that this is an alternative to getting more women into engineering, or to feminists and other progressives working to change technology from the "inside out" (e.g., Suchman, 1995). The need for technologists to exercise social responsibility for the impact of their products has been a recurring theme since Mary Shelley's *Frankenstein*. Many feminists and sociologists have read into this parable the lesson that the hapless inventor should have thought *in advance* of the consequences of his actions and *cared for* his creation once it was made; indeed, the creation himself eloquently makes this point during the stunning meeting in the glacier. Knut Sørensen, for example, argues that what is required, as part of any strategy to democratize technology, is for engineers to adopt a "professional ethic of caring" such that they nurture and "bring up" new technologies, much as parents do their children, learning along the way how best to do the job (see Andersen & Sørensen, 1994).

This vision resonates strongly with Hilary Rose's memorable call for a "unity of hand, brain, and heart" in a transformed practice of science (Rose, 1983). Rose argues that women are more likely to bring a caring ethic and rationality to technical work because their position in the sexual division of labor means that they generally do (or are socialized to do) more caring work than men (Rose, 1983, 1994, ch. 2). Feminist standpoint epistemology has not been formally applied to technology, theoretically or empirically, although it has long been an article of faith of many feminist activists including myself (Arnold & Faulkner, 1985) that women's entry into technology—specifically the design and development of technologies—would, by itself, begin to transform both the products of technology and its *modus operandi*. These days such claims are (rightly) seen as dangerously essentialist. But we should not lose site of the significance of "situatedness" (Haraway, 1988) with respect to technology. As some of the better research in feminist technology studies has revealed, the male dominance of engineering does gender the design of artifacts[5]—so why not the other way around? At the very least, few would argue with the notion that women designers should be more likely to "see" the needs of particular female users (e.g., for wider gangways on buses, to allow for women with young children in buggies, or for air bags that are not lethal to short women and children). As indicated earlier, however, there is very little evidence that women and men bring different styles or perspectives to engineering, and the opportunities for this may be limited as yet.

What remains crystal clear is that liberal campaigns to increase the participation of women in technology will amount to little unless they are linked to a radical vision and agenda for the transformation of technology—into a practice that is more democratic and respectful of diversity, with products which are safer, friendlier, and more useful.

ENDNOTES

1. Marxist research on the labor process has generally emphasized how social relations can be embodied in production technologies. Some constructivists do not accept such formulations. Grint and Woolgar, for example, emphasize instead our "interpretative engagement" with technology, and insist that "The politics and values of technology result from the gaze of the human; they do not lie in the gauze of the machine" (1995, pp. 292, 305).
2. The label "craft engineer" may not have meaning outwith the United Kingdom: it connotes someone who is apprenticed rather than university trained, and who usually works in the maintenance, installation, or manufacture of artifacts.
3. It is worth noting that the reductionist–holistic dualism is gendered the opposite way in science: reductionist approaches and specialisms, such as molecular biology, are generally esteemed far more highly than holistic ones, like animal behavior and primatology, which are seen as decidedly more "girlie."
4. Technology assessment is practised in some countries as a means of anticipating harmful consequences of new technologies (usually harmful environmental or health impacts) and suggesting appropriate modifications or alternatives. See Rip, Misa, & Schott (1995) for critical discussion and case studies.
5. The gendering of design more widely–encompassing aesthetic as well as engineering design—is a topic worthy of further attention, and one that could usefully be subject to the kind of approach outlined in this paper.

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