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Broken Metaphor

The Master-Slave Analogy in Technical Literature

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In November 2003, after receiving a discrimination complaint from a county employee, the Los Angeles County Office of Affirmative Action Compliance sent a memo to all its equipment vendors asking that they stop using the words "master" and "slave" in reference to computer hardware and other equipment.^{1} The memo read in part: "Based on the cultural diversity and sensitivity of Los Angeles County, this is not an acceptable identification label." The idea of slavery in ancient Egypt or classical Greece did not carry the racial connotations that make it such a hot button in the United States today. Even Hegel's famous use of the master-slave relationship to illustrate the dialectic, in 1807, has no real racial overtones, although Frantz Fanon observed that if Hegel had had any experience with African or African-American life he would not have made the progression toward synthesis seem so easy. But now things are different.

And so, predictably, the Internet flared with invective following L.A. County's decree. But I began to wonder about the ubiquity of these terms. Why is it so common to see them used in technical settings? How did the practice start? I recalled encountering them in my undergraduate electrical

engineering textbook; it struck me then as an odd choice of words, though I got used to it. I could see how a layperson might find such a casual use of the master-slave metaphor jarring or disconcerting. And then I began to wonder what black engineering students, or even professionals, thought about it. Much of my work as a social scientist has been in the area of minority-student math and science education, working on pedagogies that help underrepresented students aspire to technical careers. Did that figure of speech add to the alienation these students often report?^{2} Just how was it that a morally criminal social practice became the metaphor of choice for a ubiquitous phenomenon in engineering?

A definitive history of the master-slave metaphor in engineering literature might make a nice doctoral dissertation, but since I didn't have time for that I settled for a briefer investigation. I believe that even this sketch provides sufficient foundation for some conclusions, but readers should feel free to consider excessive brevity grounds for dismissal after they review it. My evidence came from technology historians, old encyclopedias of mechanical devices, old commercial catalogs, and even some old engineers, but the best resource I found was patent records. The master-slave metaphor is now quite common in patent descriptions that specify a control relation between two devices: a Boolean search of U.S. patents since 1976 for "master" and "slave" returned 19,708 items. These include automotive clutch and brake systems, clocks, flip-flop circuits, computer drives, and radio transmitters. Although it is not possible to perform a similar automated search of older patent records, I used the citation of previous patents for the devices mentioned above, and citations in those patents, to trace these terms backward.

It turns out that the first occurrences of the master-slave metaphor in technical settings are surprisingly recent, at least in print. I have not found any evidence of it before the American Civil War, when chattel slavery still existed in the United States. The earliest use I have found dates to a 1904 report by the astronomer David Gill describing a sidereal clock he designed for the observatory in Cape Town, which "consist[ed] of two separate instruments[:] (a) a pendulum (swinging in a nearly airtight enclosure maintained at uniform temperature and pressure) and (b) the 'slave clock' with wheel train and dead-beat escapement."^{3} Although today we associate South Africa with the racism of apartheid, at the time Gill wrote slavery had been outlawed in the Cape Colony for over sixty years, and Cape Town itself had been the home port of the Royal Navy's West African Squadron, which was deeply involved in the suppression of the slave trade in the mid-nineteenth century. Gill's biography gives no indication that he had a positive view of slavery, nor that he was a particularly enlightened colonialist when it came to that.^{4} His wife Isobel's memoir of their time spent with primarily African staff on Ascension Island similarly betrays no proslavery inclinations; on the contrary, it records her increasing respect for the Kru sailors.^{5} If Gill thought about the social echoes of the master-slave metaphor, it would have been with disapproval.

Why then choose a morally negative analogy? Perhaps this language helped emphasize his innovation. While many timekeeping systems used one main clock to control multiple secondary dials (for example, in schools, where the clockfaces in many classrooms needed to show the same time), Gill's invention coupled two autonomous clocks: a free pendulum swinging in a vacuum (the master), and another (the slave) that could keep time itself but was subject to periodic corrections from the master.^{6} Because the free pendulum did not have to power a dial, there was no drain on its momentum, and hence a great increase in its precision. The concept of a free master that did no work and a slave that followed the master's orders made for a vivid, if ethically suspect, technosocial metaphor.

In 1921, W. H. Shortt, a British railway engineer, developed a similar system with some practical improvements. Shortt collaborated with Frank Hope-Jones, director of the Synchronome Company, and over the next thirty-five years Synchronome produced nearly one hundred "Shortt Free Pendulum" clocks, which it sold to observatories all over the world. In 1924 a Major

Prince gave a lecture to the British Horological Society in which he referred to the old-fashioned secondary dials as “slave clocks.”^{7} Hope-Jones was in the audience and objected to Prince’s use of that term, suggesting that it should be restricted to free-pendulum systems. He recommended “electrically impulsed dials” as a better alternative. Prince replied that he had decided on “slave clock” deliberately because he thought it was more intelligible to the ordinary person. He further pointed out that there were only about six clocks then in existence that matched Hope-Jones’s definition, whereas there were many thousands that matched his. Hope-Jones was fighting a losing battle, and Prince’s usage for “slave clock” became increasingly common.

The earliest U.S. patent I have found in which the master-slave metaphor occurs is number 2510461, a “Multistation Microwave Communication System” from April 1946. The previous patents it cites use phrases such as “master oscillation generator” and “second oscillation generator.” Surprisingly, none of the numerous patents for flip-flop circuits use the “master-slave” terminology until number 3454935 in 1966. I was able to track down the engineer on that patent, Bud Hippisley, who kindly reviewed his course notes and exams from his undergraduate digital systems engineering course at the Massachusetts Institute of Technology in 1962. He reported that the master-slave metaphor never came up, though flip-flop circuits were covered thoroughly. Hippisley also reviewed memos from Honeywell in the early 1960s and noted that master-slave terminology was also absent from them, though he recalled that engineers at Honeywell did use it in conversation, “especially when people with asynchronous design experience came onto our . . . design team.”

The master-slave analogy is frequently used for hydraulic cylinders, as in automobile brake systems. But of nine U.S. patents for hydraulic cylinders granted prior to 1959, none employed that terminology; labels such as “main cylinder” and “receiver cylinder” and “servomechanism” were used instead. Master/slave does finally become common in patents for hydraulic cylinders after 1960. The oldest instance I have found is patent number 2882686, granted in April 1959, and even there the author introduced the terms cautiously: “In such hydraulic systems the actuating cylinder and piston assembly is generally called the ‘master’ and the actuated cylinder and piston assembly is generally called the ‘slave.’” The quote marks and explanations seem to indicate that this was not yet a common figure of speech.

The most controversial technical setting for the master-slave metaphor is in computing, probably because the general public most commonly encounters it there (as in, for example, a screen message during boot-up that refers to “master/slave bios”). The earliest usage here is probably the Dartmouth timesharing system, created in 1964. As with Gill’s clock, it appears to have been inspired by an innovative control relationship between two autonomous devices: “First, all computing for users takes place in the slave computer, while the executive program (the ‘brains’ of the system) resides in the master computer. It is thus impossible for an erroneous or runaway user program in the slave computer to ‘damage’ the executive program and thereby bring the whole system to a halt.”^{8} Gill’s social metaphor described not only a control relation but other resemblances as well; recall that the master was a “free” pendulum that did no work. Similarly, the creators of the Dartmouth system extended the metaphor beyond the control relationship, describing the master computer as the “brains”—thus implying that the slave computer is the “brawn,” despite the fact that it does as much or more calculation. It is interesting to note that this extension of the metaphor makes the same error—conflating mastery with intelligence—that human masters often make about their own slaves. And consider the phrase “impossible for an erroneous or runaway user program in the slave computer to ‘damage’ the executive program.” It is almost certain that there was no conscious intention to echo pre-Civil War discourse on runaway slaves, but that still leaves the possibility of a metaphor operating at a subconscious level.

By comparing master-slave terminology with earlier usage in technical literature, we can start to understand why it did not become common until after WWII. First, there is the issue of autonomy. The terms "master clock" and "secondary clock" made sense when only the master clock actually kept time and secondary dials merely reflected the master dial positions. When Hope-Jones insisted in 1924 that the term "slave clock" should be reserved for systems such as the ones designed by Gill and Shortt, he was making a distinction based on autonomy. Those secondary clocks could keep time independently, but still had to obey the master clock's timekeeping corrections. Interestingly, at almost the same time a new term meaning "slave" was entering the English language to describe an autonomous device meant to obey its master: "robot," from the 1923 translation of Karel Capek's 1921 play "R.U.R." (the word robot having been derived from a Czech word for slave, "robotnik"). As Hippisley emphasized, the issue of autonomy was particularly germane in cases where synchronization was required, an increasingly common situation in computing and electronics.

A second issue, closely related, is the difference that electrical signals make. Consider what it meant to drive a car before power steering. You wrestled with the wheel; the vehicle did not slavishly carry out your whims, and steering was more like a negotiation between manager and employee. Hence the appropriateness of terms such as "servo-motor" (coined in 1872) and "servomechanism" (1930s): both suggest "servant," someone subordinate but also in some sense autonomous. These precybernetic systems, often mechanically linked, did not highlight the division of control and power. But electrical systems did. Engineers found that by using an electromagnetic relay or vacuum tube a powerful mechanical apparatus could be slaved to a tiny electronic signal. Here we have a much sharper disjunction between the informational and material domains. And with the introduction of the transistor in the 1950s and the integrated circuit in the 1960s, the split became even more stark.

This coupling of immense material power with a relatively feeble informational signal became a fundamental aspect of control mechanisms and automation at all scales, including the factory. Combined with changing human managerial systems, it allowed a greater split between skilled and unskilled labor. One of the most vivid descriptions of this technosocial change can be found in David Noble's classic article on numerically controlled machine tools.^{9} Noble provides convincing evidence that digital control over lathes, milling machines, and so forth, beginning in the 1950s, was just as strongly motivated by managers' desires to reduce shop-floor control and union power as by hopes for improving accuracy or efficiency.

But the wage slave of the twentieth century is not the reason L.A. County officials banned the use of the master-slave metaphor. Its resonance with enslaved Africans of the nineteenth century is what concerned them. Which brings us to the second question: How do contemporary black engineers feel about it?

In December 2005 I sent e-mail asking this question to thirteen African-Americans who are generally ranked among the nations' top scientists and engineers. Even if I had received responses from all thirteen instead of the four who did reply, it would not have constituted a statistically significant result, but I was more interested in content than statistics. My query provoked passionate statements both for and against ending the use of master-slave terminology. One respondent who argued against restrictions wrote:

I have to admit that the first time I read a description of a master-slave flip flop (1974) was a little unnerving. It struck me as strange that a term for a social institution would be used as a metaphor for the operation of an electronic device. After I got over my discomfort, I was forced to think about the social institution of slavery in more abstract terms (separation of control and data [work], autonomous execution of the components, asynchronous execution, control points, etc.). So, in some sense, the use of the term was beneficial to my

intellectual and social development. I think we must be careful about attempts to formally control language usage because the side effects could easily outweigh the intended direct effects. Richness of language and richness of thought are intertwined.

The other side was equally eloquent:

When I first taught digital logic, around 1992, I did not recognize the awkwardness of the term until I, one of the few African-Americans in the room, was standing in front of a class of sixty students. I recall mumbling. For flip-flops, the terminology makes little sense, since there is no amplification taking place. The master latch is connected directly to the input and eventually the slave latch acquires the value of the master. The master is commanded by the inputs just as much as the slave is. Furthermore, in real implementations, this master-slave arrangement is not apparent; cleverly cross-connected gates achieve the desired result without independent latches.

The same correspondent later added:

[M]y first thought was to ignore your email as a complaint that engineering terminology was not "politically correct." Then I remembered my own misgivings about the term "master/slave flip-flops." After a little more thought, it became clear that the term was not very descriptive. Your historical essay pointed out that it was introduced only recently, long after the devices were in use. It has to go.

When I began this research, I was pretty much in the same camp as the first correspondent. But the second changed my point of view. It is one thing to hear objections from people who are in the business of promoting ethnic sensitivity, quite another to hear them from hard-core geeks who have devoted their careers to their love for science and technology. If the master-slave metaphor affected these tough-minded engineers who had the gumption to make it through a technical career back in the days when they may have been the only black persons in their classes, what impact might it have on black students who are debating whether or not to enter science and technology careers at all?

The second correspondent raises another question: why use the master-slave metaphor when there is not a control relationship between two devices? This echoes Hope-Jones's objection to Prince's use of the term "slave clock," but since WWII this indiscriminate usage has become widespread. In fact, the most common encounter we have with it, as the phrase "master/slave bios" flashes onscreen when a computer boots up, is entirely erroneous. As the online resource PC Guide puts it: "Note that despite the hierarchical-sounding names of 'master' and 'slave,' the master drive does not have any special status compared to the slave one; they are really equals in most respects. The slave drive doesn't rely on the master drive for its operation or anything like that, despite the names (which are poorly-chosen—in the standards the master is usually just 'drive 0' and the slave 'drive 1'). The only practical difference between master and slave is that the PC considers the master 'first' and the slave 'second' in general terms."^{10}

Why use this terminology if it renders a less accurate technical description, implying a control relationship that does not exist? There are several possible explanations. Some scholars would see it as evidence of sinister ulterior motives—a racist desire to mark technology with white privilege, or the Freudian emergence of a sexually charged pathology of dominance.^{11} I don't doubt the existence of racism, or of sadomasochism (though I don't think that the latter should be considered either a pathology or a suspect in technosocial power grabs). I don't doubt that somewhere out there exist a few racist engineers to whom the "sinister ulterior motive"

explanation applies. But I do doubt that they constitute a significant number. After all, William Shockley's ideas about race met with overwhelming rejection from his engineering colleagues—indeed, made him a pariah.^{12}

Another possibility is that the metaphor caught on because it ameliorates a tension between a desire for more autonomous machines and a desire to retain human mastery. That tension is a familiar theme in the popular imagination of technology: examples include Mary Shelly's *Frankenstein*, the African-American story of John Henry, and Capek's "R.U.R.," to name just a few. It is sometimes expressed in terms of threats to job security. In his 1832 book *On the Economy of Machinery and Manufactures*, for example, Charles Babbage described three levels of mathematical thought: the first the realm of professional mathematicians, the second that of applied technicians, and the third belonging to mere mathematical workers. Babbage suggested that the third level could be replaced by his Difference Engine. Later he proposed the construction of an even more complex device, the Analytical Engine, which would be close to a general-purpose computer. Luigi Frederico Menabrea, an Italian engineer, published an article in which he suggested that the Analytical Engine could replace the applied mathematicians at Babbage's second level. Ada Lovelace, who translated Menabrea's article, felt compelled to assure readers that Babbage's idea would not threaten what we would now call white-collar professions: "The Analytical Engine has no pretensions whatever to originate anything. It can do whatever we *know how to order it* to perform. It can *follow* analysis; but it has no power of *anticipating* any analytical relations or truths."^{13} By referring to a master/slave relation in devices, professionals may reassure themselves that they will remain masters of machines.

A third possibility is that the master-slave metaphor became increasingly common due to positive feedback: the more it was used in engineering, the more it had an engineering-like sound to it—a kind of meme or slow-moving fad. By this theory any figure of speech would have caught on, and it was sheer chance that it happened to be this one. But this begs the question, because there were indeed alternative terms in use, such as "primary" and "secondary." Positive feedback may have played a role, but the selection still has to be explained.

The tendency of scientists and engineers to think of their professions in terms of opposition to culture suggests another possible explanation. Sharon Traweek, for example, noted the curious promotion of impolite behavior among physics grad students.^{14} In a particularly illuminating instance, she observed that one student was constantly stuffing bread in his mouth at restaurants. His professors reacted with amusement, and encouraged him by telling the waiter to bring him more bread. When she asked one of them about it, he explained that being unconscious of social mores was a good sign for a future physicist, because physics transcends culture. Perhaps this kind of emphasis on a technical identity is at work here, too, and the master-slave metaphor is attractive to engineers because its free use "proves" that they inhabit a nonsocial or culture-free realm, which is a matter of professional pride. That would explain the vociferous objections in technical listservs to the 2003 L.A. County memo, which challenged any conviction that the technological realm truly transcends culture.

Finally, I should mention one of the explanations proposed in the 2003 listserv traffic, which was essentially that much engineering terminology is boring, and engineers themselves are stereotyped as boring, so they would be attracted to the master-slave figure of speech simply because it makes their work seem more interesting.

Hope-Jones's objection to Prince's use of the term "slave clock" in 1924 was not motivated by the politics of race. He wanted what any good engineer desires: accuracy. In that spirit, perhaps we can agree to get rid of the master-slave metaphor in cases where it is manifestly incorrect. But it seems to me that in addition to accuracy there are three ethical issues at stake here. The first concerns a point made by one of the African-American scientists quoted above on the risks of trying to control expression: "Richness of language and richness of thought are intertwined."

Many others made similar comments in the listserv traffic sparked by the L.A. County memo, often in hostile and inflammatory language. While I have little sympathy for those who use accusations of political correctness as political ammunition, I have a strong commitment to free speech and the promotion of open thought in public domains, which entails not only the protection of legal rights but also the protection of a climate in which open conversation can occur. Several of my colleagues in queer theory and allied disciplines have pointed out that "master/slave" has sexual connotations that they would be perfectly happy to defend. So I think that any solution to this problem needs to actively avoid restrictions on the free expression and exchange of ideas.

Second, as a social scientist involved with efforts to increase the recruitment and retention of underrepresented minorities in science and engineering, I cannot condone practices that further the alienation of these students.^{15} So I also think, echoing the African-American engineer who concluded that "It has to go," that the laissez-faire position is untenable. Note that this is potentially in conflict with my first observation.

Which brings me to the third ethical issue. In many cases of culture clash—enforced veiling of women in Islamic countries, for example—controversies arise over the imposition of First World mores on Third World populations.^{16} On the one hand, a practice may seem unethical from a Western viewpoint; on the other, allowing the Western viewpoint to determine non-Western cultural practices just seems like an updated version of colonialism. One solution to this dilemma has been to work through indigenous opposition groups that can encourage change through more democratic means, with Western support. In a similar fashion, I think that a change in technical terminology can be brought about through professional technical organizations, which are analogous to a legitimate indigenous voice in the postcolonial situation. External groups (such as the L.A. County Office of Affirmative Action Compliance) could provide support (by, for example, documenting a problem and raising public awareness of it), in a manner analogous to the way that international civil rights groups operate. Taking such an approach would honor the first two ethical issues while resolving their conflict. Of course, nonengineering users and students who might go into engineering are also affected by the terminology used by engineers, so leaving it up to the technical organizations does not allow all affected parties an equal voice, but I think this approach should be the first attempted.

The variety of ways in which the same control relationship is described in other languages may serve as an inspiration. While the Dutch have the term "slave clock" (*slaafklok*), for example, they also use "daughter clock" (*dochterklok*). In Germany one finds *Mutteruhr* and *Tochteruhr* (mother clock and daughter clock), and their equivalents in France as well (*horloge-mere* and *horloge-fille*). The Germans also use *Hauptuhr* (head clock) and *Nebenuhr* (next-to clock). One of my African-American correspondents reported that in his digital-circuits class he has been using "boss" and "worker." Surely, between our cultural resources and our desire for technical accuracy, we can do better than "master" and "slave."

^{1} Reuters, "'Master' and 'Slave' Computer Labels Unacceptable, Officials Say," 26 November 2003, <http://www.cnn.com/2003/TECH/ptech/11/26/master.term.reut/index.html> (accessed 15 January 2007).

^{2} See, for example, Gary Lee Downey and Juan Lucena, "Weeding Out and Hiring In: How Engineers Succeed," in *Cyborgs and Citadels: Anthropological Interventions in Emerging Sciences and Technologies*, ed. Gary Lee Downey and Joseph Dumit (Santa Fe, N.M., 1997); Ron Eglash, "Race, Sex, and Nerds: From Black Geeks to Asian-American Hipsters," *Social Text* 20 (2002): 49–64; and Lois Powell, "Factors Associated with the Underrepresentation of African Americans in Mathematics and Science," *Journal of Negro Education* 59 (1990): 292–98.

{3} The Gill report is quoted by clock inventor Frank Hope-Jones in a lecture to the British Horological Institute on 19 April 1923. Hope-Jones remarks: "Here the same idea is well expressed, but is based on a checked gaining rate instead of synchronization and the term 'slave clock' first used." I am indebted to James Nye, secretary of the Electrical Horology Group, for this information.

{4} George Forbes, *David Gill: Man and Astronomer* (London, 1916).

{5} Isobel Gill, *Six Months in Ascension: An Unscientific Account of a Scientific Expedition*, (London, 1878).

{6} Although timekeeping systems using a main clock and secondary clocks, as in a school, are now called master-slave clock systems, that is a fairly recent development. The Standard Electric Time Company of Springfield, Massachusetts, for example, lists these as "master" and "secondary" clocks in their catalogs from 1887–90 and 1909. Jeffery Wood, an expert on the history of Standard Electric, says the term "slave clock" came into informal use there after about 1945.

{7} Thanks to David Read for his account of this event.

{8} John Kemeny and Thomas Kurtz, "Dartmouth Timesharing," *Science* 162, no. 3850, 11 October 1968, 223–68.

{9} David Noble, "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools," in *Case Studies on the Labor Process*, ed. Andrew Zimbalist (New York, 1979).

{10} <http://www.pcguides.com/ref/hdd/iff/ide/conf/Jumpering-c.html> (accessed 15 January 2007).

{11} Sally L. Hacker, *Doing It the Hard Way* (Boston, 1990).

{12} Joel N. Shurkin, *Broken Genius: The Rise and Fall of William Shockley, Creator of the Electronic Age* (New York, 2006).

{13} Philip Morrison and Emily Morrison, eds., *Charles Babbage and His Calculating Engines: Selected Writings by Charles Babbage and Others* (New York, 1961), 284 (italics in original).

{14} Sharon Traweek, "Uptime, Downtime, Spacetime, and Power: An Ethnography of the Particle Physics Community in Japan and the United States" (Ph.D. diss., University of California—Santa Cruz, 1982). In the transition between Traweek's dissertation and its publication as *Beamtimes and Lifetimes: The World of High Energy Physicists* (Cambridge, Mass., 1988), parts of the section referenced here were cut.

{15} See, for example, Ron Eglash et al., "Culturally Situated Design Tools: Ethnocomputing from Field Site to Classroom," *American Anthropologist* 108 (2006): 347–62.

{16} Enforcement is really at the heart of this controversy, since many Islamic feminists have made solid arguments that veiling itself is not problematic as long as the decision is up to the individual. See, for example, Muslim Women's League, "An Islamic Perspective on Women's Dress" (2006), <http://www.mwllusa.org/publications/positionpapers/hijab.html> (accessed 11 January 2007).

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