ABSTRACT

SAMUEL FLORMAN AND A LITERATURE OF TECHNOLOGY

by
Paul F. Sharke

In 1996, engineer and author Samuel Florman asked why engineering and technology had been represented only lightly in literature. From a mere handful of books dealing with this topic, he named *The Control of Nature* (1989), by John McPhee, *Zen and the Art of Motorcycle Maintenance* (1974), by Robert Pirsig, and *The Soul of a New Machine* (1981), by Tracy Kidder, as being among the best examples of a literary expression of engineering. These three works are examined here in light of Florman's own four books on the subject of engineering, *The Existential Pleasures of Engineering* (1976), *Blaming Technology* (1981), *The Civilized Engineer* (1987), and *The Introspective Engineer* (1996), with particular attention directed towards Florman's search for an expression of the creativity and passion inherent to engineering.

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by
Paul F. Sharke

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APPROVAL PAGE

SAMUEL FLORMAN AND A LITERATURE OF TECHNOLOGY

Paul F. Sharke

Dr. Robert E. Lynch, Thesis Adviser — Date
Professor of English, Department of Humanities and Social Sciences, NJIT

Dr. Burt Kimmelman, Committee Member — Date
Assistant Professor of English, Department of Humanities and Social Sciences, NJIT

Dr. Thomas B. Swanzey, Committee Member — Date
Associate Dean, Edward Williams College, Fairleigh Dickinson University

BIOGRAPHICAL SKETCH

Author: Paul F. Sharke

Degree: Master of Science

Date: May 1998

Undergraduate and Graduate Education:

- Master of Science in Professional and Technical Communication
  New Jersey Institute of Technology, Newark, NJ, 1998

- Bachelor of Science in Engineering Technology
  New Jersey Institute of Technology, Newark, NJ 1982

- Associate of Applied Science in Mechanical Design Technology
  Somerset County College, North Branch, NJ 1980

Major: Professional and Technical Communication

To the memory of Joey S.

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INTRODUCTION

When engineer Samuel Florman wrote *The Introspective Engineer* in 1996 (henceforth, *IE*), he echoed Aldous Huxley in *Literature and Science* (1963) by asking "why the creative artists of our time [do not] write about engineering" (107). By asking this, Florman renewed his search for an artistic expression of engineering that he had begun in 1976 when he wrote *The Existential Pleasures of Engineering* (henceforth, *EP*). In the twenty years separating these two Florman books, he wrote two more, *Blaming Technology* in 1981 and *The Civilized Engineer* in 1987 (henceforth, *BT* and *CE*, respectively).

In *The Introspective Engineer*, Florman summarizes the few existing examples that portray engineering as the subject of contemporary literature. John McPhee's *The Control of Nature* (1989) and David McCollough's *The Great Bridge* (1972) and *The Path Between the Seas* (1977) he calls "splendid" and "among the very best nonfiction books of our time" (108). Henry Petroski's *The Pencil* (1989) and *The Evolution of Useful Things* (1992) along with Steven Levy's *Hackers* (1984) and *Insanely Great: The Story of the Macintosh* (1994), Florman calls "delightful and informative," but he categorizes them as "represent[ing] an offering from the technical community rather than an embrace by the artistic." Alexander Solzhenitsyn's *The First Circle* (1968) he labels "a work of powerful fiction," and Robert Pirsig's *Zen and the Art of Motorcycle Maintenance* (1974) he says "blazed across the literary sky, albeit eccentrically." With the exception of these "tantalizing glimpses," and Tracy Kidder's *The Soul of a New Machine* (1981), Florman says, "technology is largely absent from contemporary literature, except where it serves as a foil for satire or a backdrop for scenes of alienation" (108-09).

A look at Florman's educational and professional background reveals why he is interested in a literature of technology. A B.A. in engineering from Dartmouth College and an M.A. in English literature from Columbia University put him mid-span on the bridge between engineering and the humanities. A practicing engineer, Florman attempts to bring together in his writing the technological and humanistic pursuits. He has sought the literary and artistic expression of engineering. He has pushed for an increased liberal arts content in the education of engineers.

Among the many ideas that Florman covers in his own books, the notion that creativity, beauty, and passion are elements that are essential to the engineering endeavor is an especially bold one. As an engineer who also writes, Florman would be expected to find evidence of these elements in all sorts of technological activities. Would other writers who were not trained in technology find similar evidence? This thesis will attempt to find such links between Florman's writing and that of three contemporary authors: McPhee, Pirsig, and Kidder.

In seeking a literary expression of engineering, we will examine three books described by Florman as significant to the engineer's craft: *The Control of Nature*, *Zen and the Art of Motorcycle Maintenance*, and *The Soul of a New Machine.* We will study what has been written about three increasingly abstract endeavors: the building of levees, the maintenance of motorcycles, and the building of computers. Doing so, we will move from the physical beauty of human-made objects, to the intellectual beauty of underlying form, to the abstract beauty of logic. In another sense, we will move from civil engineering, to mechanical engineering, to computer engineering, tracing a historical path that moves farther and farther away from the natural, sensible world.

In searching for the engineers' Shakespeare (*EP* 96), that person who will produce a "work in which engineering and technology are imaginatively depicted as part of the human scene," (*IE* 112) I hope to illuminate Florman's ideas on creativity and passion as they are manifested in the act of engineering. Thus, we follow Florman's quest for a literary expression of engineering.

CHAPTER 2

COWBOYS, SOLDIERS . . . ENGINEERS?

In his preface to *The Existential Pleasures of Engineering*, Florman explains his interest in exploring not what it is that engineers do, but how "engineers think and feel about what it is they do" (x). About halfway into this book, he laments the neglect by the poets and creative writers of today to examine the subject of engineering. Nor is he surprised either that few engineers have taken up the search for a literary expression of engineering. "Somehow the engineer has veered away from the sentimentality of the past without showing any inclination to search for new personal truths" (96).

What is it about engineering that seems to repress a verbal expression, Florman asks. He sees a common bond among engineering and soldiering and cowboying in that none of these vocations seem to attract those who are otherwise poets or writers. "The romance of soldiering has been imparted to us, not by soldiers, but by minstrels." Soldiering has given writers a wealth of material, but its writers, for the most part, have come from outside of the military. "The cowboy is no more glib than the engineer, but he has been glorified in song and verse" (96). Here, too, the chroniclers of the wild west have come mainly from outside the ranks of the practitioners.

History's most memorable characters, Florman tells us, have been made so through the work of poets and writers:

> Even the great lovers of history are known to us, not because of anything they said, but because of what poets have said about them. Henry V never exclaimed, "Once more unto the breach . . . " He might have been a very dull fellow. The engineer may merely be waiting for his Shakespeare. (96)

For whatever reason, engineering and technology are only lightly represented in literature, and as such, are separated from the realm of understanding by nontechnologists. The terrible thing about this is that it promotes the image of the engineer as "an uptight, inauthentic person who sees with a dead man's eyes." So do the studies that Florman cites which show engineers to be "bourgeois in their lifestyles . . . middlebrow in their tastes," and characterized by

> an indifference to human relations, to psychology and the social sciences, to public affairs and social amelioration, to the fine arts and cultural subjects and even to those aspects of the physical sciences which do not immediately relate to engineering. (91)

Florman likens society's perception of engineers as stemming from the same pre-liberation rules that forced upon women a "self-image [that was] molded by society in a subtle and devious manner." It was useful for society if women acted in certain predictable ways, Florman claims, and engineers are perhaps expected to act in accordance with society's expectations as well. In relating the plot of Maurice Samuel's story *The Devil That Failed*, Florman compares engineers to the protagonist in the story who, not knowing he has been abducted by a group of "malicious midgets," sees himself as a "clumsy giant." Society's "humanist midgets" have convinced engineers that they are "oafs, emotionally speaking." Yet, engineers not only fail to "to contest this defamation," they supply the humanists with ammunition that helps fortify the attack (96-97). Florman points out one such instance where an engineer supplies bullets for the other side. An article entitled "Science: A Technocratic Trap," by Theodore Roszak, which appeared in *The Atlantic* (July 1972), later draws criticism from a civil engineering professor who writes to *The Atlantic*'s editor:

> There have always been people who could not bear the pain of thinking, or of planning ahead, who wanted to return to a simpler era, to the safety of their grandfather's knee, to the womb. And such people have always resented the way that rational, foresighted people got ahead of them, and so they have cut them down to size by attacking their very base, their rationality. The sad thing, today, is to see some modern intellectuals subscribing to such patterns of attack, and actually cutting off their own roots in rationality. (qtd. in *EP* 97)

Roszak responds to the civil engineer's criticism:

> It is not primarily science I pit myself against in what I write. Rather, the wound I seek to heal is that of psychic alienation; the invidious segregation of humanity from the natural continuum, the divorce of visionary energy from intellect and action. (qtd. in *EP* 97)

Florman tells us that the engineering professor missed Roszak's point completely by defending rationality. "Perhaps," Florman writes, engineers "live in closer touch with the 'natural continuum' than most people do, including most philosophers" (98). The lives of engineers are filled with passion and emotion, he continues. But, it is clearly the attitude reflected by the civil engineering professor that closes engineers out from the rest of the world, from the pleasures that come from things unanalyzed. By taking "practicality to be their province," engineers give the impression that they have no emotional depth, no passion beyond cold truths (96).

Florman points to examples of engineers' reticence by reviewing what prominent practitioners had written about their work. Taking passages from two collections of engineering essays, he discovers that most of these engineers "write of their life's work with scarcely a glimmer of passion." He excuses them to some extent by saying they may very well be "inhibited" by the lofty positions they hold. Yet, engineers in lower positions show similar reserve, Florman says, leading him to wonder why (95).

He proposes that engineers have been forced by society to view themselves as emotionless and coldly calculating (96). Indeed, coming to accept this image, engineers work to reinforce it in the minds of the humanists, thus closing the circle. But Florman claims that engineers "are proud of their profession, anxious to sing its praises." In spite of the "fact that engineers are inarticulate" and that they "lack poetic flair," Florman vows to track down the very soul of engineering, which, he believes, stirs up from humanity's "basic impulses" and "sublime aspirations" (98).

It is not enough to take Florman at his word, however. Show us the passion, his readers ask. Prove to us that emotion has some place in the world of engineering. Show us that which exists beyond the "purely cerebral" (98). If Florman is able to find the engineer's world faithfully depicted in recent literature, though, why should it matter? Should engineers really concern themselves with how society perceives the profession and its practitioners? Would showing engineers and potential engineers those sides of the profession that transcend the numerical plane help engineers in particular, and society in general? Florman believes that it does matter, that they should be concerned, and that it would help. Florman sums up his platform neatly in this passage:

> For those of us who are engineers, the poetic vision of our profession can serve to reinterpret and refine our own rough-hewn feelings. For young engineers, or would-be engineers, it can give some indication of the glorious inheritance that is theirs. (119)

As for society's benefit, he says,

> For those who hold to the view that engineering is soul-deadening and anti-existential perhaps the words of poets, novelists and philosophers will open some new and unexpected prospects. (119)

Florman sees a literature of technology as one way of fulfilling his desire to elevate engineering to a higher esteem, through the internal promotion of engineers' self-view, and through external promotion of engineering to everyone else. Florman tells us that the humanists need not be surprised when engineers call upon them for help in this endeavor. For though engineers are stereotypically inarticulate, a long standing association connects them with artists. Engineers "help to make the world which it is [the artist's] destiny to interpret" (119). The engineer creates for artists the tools with which, and surfaces upon which, they interpret the world. It is only natural then to expect the artists to reciprocate, to help express the "satisfaction inherent in engineering" (120).

Briefly, then, that is the quest Florman undertakes in *The Existential Pleasures of Engineering*. In his later books, Florman alters his course somewhat, responding to both the criticism from engineers about his earlier work and the changing opinions of society regarding technology and engineering. In *Blaming Technology*, he seeks to defend the profession from its critics. But he also begins to realize that engineers aren't all that interested in the interpretation and elevation of their work by artists. Engineers would take on the tasks that needed doing regardless of society's spurning of the profession. One engineer says to Florman, "Look, some of us were attracted to engineering because we're good at figures and we're not good with people. We can do our work and solve most of the problems you give us, but please don't try to drag us into longwinded discussions about the meaning of life." Mulling over this revelation, Florman realizes that "single-minded dedication" to their work and a disdain for introspection are traits common to many engineers. He insists, however, that if society could appreciate engineering as "the splendid manifestation of humanity that it is," then many engineers might "feel less isolated and less reluctant to participate in the other aspects of community life" (149).

By the time *The Civilized Engineer* is published, Florman writes "Technology is 'in' again" (x). Engineering has survived the turbulent environmental movements of the 1970s and 80s. Yet, while enrollment in engineering schools is up, for many students their interest in engineering is propelled solely by the promise of gainful, steady employment. Where is the idealism that used to accompany engineering students, Florman asks. Where is their desire to help humanity? Florman regrets the "waning of enthusiasm among would-be engineers, and the growth of cool, calculating self-interest" (23). Florman says, "In its moment of ascendance, engineering is faced with the trivialization of its purpose and the debasement of its practice" (xi).

Florman affirms his belief in the single-mindedness of many good engineers, saying that it is "unrealistic to expect engineers to be artists or poets or literary scholars" (16). He persists, however, in selling the idea that engineers who are too absorbed in their work could miss a chance at a fulfilling life. Toward the end of this book, Florman writes:

> In the non-verbal creative recesses of the engineer's mind, I believe that flexibility and variety—poetry, art, music, stories, myths—have a constructive role to play. I recognize that this is difficult, if not impossible, to prove, and that a case can be made for the creativity of the obsessively single-minded engineer. Nevertheless, there are many examples of broadly cultured scientists and engineers who derived technical inspiration from humanistic or artistic thought. (184)

In the preface to *The Introspective Engineer*, Florman says that the engineers he discussed in *The Existential Pleasures of Engineering* who were indifferent to "human relations, to psychology and the social sciences" have made strides in moving beyond their narrow focus. Engineers, today, are out in the world, "seeking a better understanding of themselves" (*IE* xi). Given this improvement in the engineer's condition, Florman renews his call for increasing the visibility of engineers in society. Along the way, he refines his earlier reasons for wishing this were so. One reason, Florman says, is to attract good people to the profession. A second reason is to inform politicians, who for the most part are not technically trained, about the complex issues facing an increasingly technological society. A third reason is that any society that ignores a part of its culture, in this case engineering, "becomes impoverished." Finally, Florman offers a fourth reason as to why engineering needs better visibility: its approach to problem solving is unsurpassed by any other endeavor; it is what a world filled with trouble needs (4-8).

CHAPTER 3

CONCRETE CONTROL

Florman summarizes John McPhee's *The Control of Nature* by calling it a consideration of the "'heroic chutzpah' that drives people to challenge mudslides in Los Angeles, floods along the Mississippi, and volcanoes in Hawaii" (*IE* 108). Of the three books under consideration in this thesis, it is McPhee's book that comes closest to discussing Florman's profession of civil engineering. This thesis will limit itself to the first of the three essays in McPhee's book, entitled "Atchafalaya."

Florman says that civil engineering was the first engineering specialty to emerge from engineering's original military beginnings. He traces the birth of civil engineering to the 1750s when John Smeaton began referring to himself as a civil engineer in order to separate his work—building "bridges, harbors, and lighthouses"—from the war-waging pursuits that had until then been engineering's association. (*CE* 51). When the word was used by Shakespeare, it was with its original military connotation:

> For 'tis the sport to have the engineer
> Hoist with his own petar (*Hamlet* 3.4.207-08)

Florman tells us that in Smeaton's day engineering was still very much a practical endeavor, little complicated by the mathematics and science that define the profession today (*CE* 46). It is a romantic description, perhaps, that best fits the civil engineer of Smeaton's day: "his wrestling with the elements, his love affair with nature, his yearning for immensity" (*EP* 126). This version crops up repeatedly in Florman's writing, one of a young, worldly-wise individual, rugged and charismatic, stooping down to tie on field boots for another day as the hero. This engineer is no nerd.

Indeed, the feats of civil engineering are quite staggering. It seems normal to admire those who undertake great public works, and easy to appreciate the sense of control civil engineers must feel as they move mountains and reroute rivers and cross chasms. These activities express humanity's earthly dominion on the largest scale. The massiveness of these works relative to the size of the workers lends vigor to the trite expression *awesome*.

Of course, by talking in this way, we're harking back to a time that Florman dubs "the Golden Age of Engineering" (6). The years between 1850 and 1950, he says, were a period in which engineering, a profession that had matured beyond mere craft, blossomed. Florman laments the passing of this time when engineers could do no wrong. So successful was their application "of the scientific method to practical problems" that the engineers of the Golden Age thought that their approach could discover "social and moral truths" just as it had discovered scientific laws (6). Consider John Roebling, the Brooklyn Bridge designer and student of Hegel, who subscribed to the idea that humanity could free itself "from the irrationality of history by mastering nature"; or Herbert Spencer, who saw "proof" in Darwinian evolution that society was "governed by scientific laws, just as nature was"; or Frederick Taylor, the engineer responsible for giving to industry time and motion studies, who, Florman says, "considered himself a prophet whose 'scientific principles' would settle all social conflicts." From Roebling, to Spencer, to Taylor, to the many engineers who "saw their work as the carrying out of the Christian mission of subduing the earth for the benefit of man and for the greater glory of God," this was a time of a confident, unstoppable profession (8).

Even today, such hubris is not unknown. McPhee, describing the role of the Army Corps of Engineers in controlling the Mississippi River, says, "the Corps has been conceded the almighty role of God" (23). To the inhabitants of the Mississippi delta, the Corps is the folks in charge, the people who dole out the life-giving water according to a formula that is supposed to balance many conflicting needs. Even the state of Louisiana is at the mercy of the Corps: during a flood in 1983, water swirled high around a maximum-security prison, threatening to spill into it despite a series of dikes and retaining walls. Faced with the possibility of busing convicts to dry ground, and the dangers inherent to transporting prisoners, "the state went on its knees before the Corps: Do something." They did. Opening the gates along a river control structure, "the Corps caused the water at the prison to go down" (53).

Florman reminds us of a passage from Paul Valéry about the constructor and the urge to straighten a world of disorder, to complete a world that is not quite finished. Florman calls this compulsion to fix the world the engineer's "most obvious existential gratification" (*EP* 120). McPhee reflects upon this same compulsion by quoting from a Corps booklet that describes its efforts in the delta: "Society required artifice to survive in a region where nature might reasonably have asked a few more eons to finish a work of creation that was incomplete" (64).

Civil engineering is perhaps more closely tied to the natural world than are the other branches of the discipline, at least when it comes to coping with fire and flood. Exploring Florman's views on the relationship between engineering and nature, we find him suggesting wrestling as a metaphor, it being "neither war nor submission" (*IE* 84). Maybe today it isn't war, but during the Golden Age that Florman describes, it may have been. Indeed, a large part of *The Existential Pleasures of Engineering* is devoted to tracing the history of engineering from the Golden Age to the present (i.e., 1976) in an effort to address criticism of technology as being against nature. With nature inflicting upon humans "unrelenting hardship," who is to say that going to war with it wasn't an apt approach (6)? In *The Introspective Engineer*, Florman cites seventeenth-century philosopher John Locke who wrote, "The negation of nature is the key to happiness" (82).

McPhee, in fact, makes it clear that it was nothing but war. "Nature was not always the only enemy," he tells us, describing how the Corps of Engineers fought not only nature, but the actions of the inhabitants that lived along the Mississippi River (41). He continues,

> Beginning in the eighteen-fifties, these notions were the subject of virulent debate among civilian and military engineers. Four major floods in ten years and thirty-two disastrous crevasses in a single spring were not enough to suggest to the Corps that levees alone might never be equal to the job. The Corps, as things stood, was not yet in charge. District by district, state by state, the levee system was still a patchwork effort. There was no high command in the fight against the water. In one of the Corps' official histories, the situation is expressed in this rather preoccupied sentence: "By 1860, it had become increasingly obvious that a successful war over such an immense battleground could be waged only by a consolidated army under one authority."(37)

Clearly the Corps had war in mind when it was assembled into a unified effort to control the river. Elsewhere, McPhee quotes from a Corps' film about the Mississippi:

> This nation has a large and powerful adversary. Our opponent could cause the United States to lose nearly all her seaborne commerce, to lose her standing as first among trading nations . . . . We are fighting Mother Nature . . . . It's a battle we have to fight day by day, year by year; the health of our economy depends on victory. (7)

Florman, too, has examined the Corps of Engineers. In *Blaming Technology*, Florman devotes a chapter to the Corps' activities to demonstrate how the work of engineers "is responsive to the needs and desires of the community in which they live." Explaining briefly the history of the Corps, Florman describes how it is really a force of "32,000 civilian engineers, technicians, and other civil servants" whose activities are loosely overseen by a "mere 300 Army officers." What's more telling, Florman continues, is the manner in which Corps projects are initiated, "not by any arm of the Army, but by the Public Works Committees of Congress and the Public Works Subcommittees of the Appropriations Committees" (44). The Army's part in all this comes about merely from tradition, we are told, a throwback to the time of Smeaton when engineering was a military endeavor.

Another point Florman makes is that the Corps' project list is reviewed annually, under the Public Works Appropriations Act, to determine which projects are funded. This renders the Corps "supremely sensitive to every wish of Congress," hardly befitting the public's image of "an arrogant, unresponsive bureaucracy" (45-46). The Corps merely acts on the will of the people. Indeed this is a current that runs throughout Florman's books: engineers are servants to society; engineers are not the people who make decisions, but the ones who carry them out (*EP* 37). If that's the case, then we should consider the Army Corps of Engineers to be merely a very large public servant.

Where Florman concentrates on McPhee's reference to "heroic chutzpah" that surrounds the engineers in his book, McPhee concentrates more on the haughtiness that seems to surround the ventures of the Corps. McPhee describes one critic of the Corps:

> A professor of law at Tulane University, for example, would assign [the Corps' activites in the delta] third place in the annals of arrogance. His name was Oliver Houck. "The greatest arrogance was the stealing of the sun," he said. "The second-greatest arrogance is running rivers backward. The third-greatest arrogance is trying to hold the Mississippi in place. The ancient channels of the river go almost to Texas. Human beings have tried to restrict the river to one course—that's where the arrogance began." The Corps listens closely to things like that and files them in its archives. (11)

Is this a criticism of the Corps? Or, is it a criticism of humanity? If we hear Florman correctly, the Corps is only acting in the interest of the public. Florman does not include engineers among the people "who appear to be in control of our society—the lawyers, writers, politicians, and business managers" (*BT* 129). Engineers today are anything but arrogant, he would say, although engineers of an earlier time may well have been. "The towers of arrogance were demolished by the environmental crisis" (*EP* 56). Today's engineers are "intelligent, energetic, unassuming" (93) and "often found among those to whom ostentation is unappealing" (*IE* 95). McPhee finds sentiment of a similar tone from one of the Corps' own engineers:

> Bayley is quick to answer—Fred Bayley, a handsome sandy-haired man in a regimental tie and a cool tan suit, with the contemplative manner of an academic and none of the defenses of a challenged engineer. "Anything can fail," he says. "In most of our projects, we try to train natural effects instead of taking them head on. I never approach anything we do with the idea that it can't fail. That is sticking your head in the sand." (25)

This passage introduces the kind of engineer we expect to meet after reading Florman. "Even the most cautious engineer recognizes that risk is inherent in what he or she does," Florman writes (*CE* 71). The engineers of today, unlike those who lived during the Golden Age, have undergone a humbling—they have been held accountable for past mistakes. "The self-satisfaction of our professional forebears now haunts us like a bittersweet memory of vanished youth" (*EP* 16). Still, engineers act on behalf of the public, balancing safety against cost. Florman explains how every design reflects tradeoffs between absolute reliability and infinite cost (33). Reading *Engineering Progress Through Trouble* "is a humbling and frightening—but in the end exhilarating—experience," Florman says. "To be willing to learn through failure—failure that cannot be hidden—requires tenacity and courage" (*CE* 72).

The study of failure in engineering design brings to mind Henry Petroski's *To Engineer is Human* (1982). Petroski contends that it is failure alone which stops a continually diminishing safety factor. Pushing their designs closer and closer to the limits of material strength, engineers tempt failure until a part breaks catastrophically. When this happens, property is lost, people are often killed or injured, and, in response, the factor of safety is raised anew. Be that as it may, it doesn't diminish the fear of material failure held by every engineer who designs structures or machines or computers upon which people's lives depend.

Failure scares even the Corps. McPhee writes about a control structure along the Mississippi that was finished in 1963. A test of the structure was not administered until a decade later when unusually high winter-water levels, coming before a rainy spring that swelled the entire watershed, and after a ten-year period of sedimentation that raised the high water mark even higher, led to "a slab of water six stories high, spread to the ends of perspective" (27). Unbeknownst to the engineers in charge, the control structure—its gates agape to let the raging water run—was being excavated along its underside by the river's "swirling power" (28). A professor of civil engineering walked out on to the structure. He felt the structure, which weighed probably 200 thousand tons and stretched for a distance that would take a 100-yard dasher twice the usual time to run, shake like "the platform at a small rural train station when 'a fully loaded freight train goes through'"(27).

Some reminisced about similar water levels in the 1927 flood. One story reported a train, loaded with coal, being parked upon a bridge to keep the crossing still. The bridge, "vibrating in the floodwater, produced so much friction that the coal in the gondola caught fire. Soon the bridge, the train, and the glowing coal fell into the water" (30).

With high water continuing throughout the spring, the undermining of the control structure became so great that a part of it "dipped, sank, [then] broke" (30). Later, when engineers crawled out onto the structure to inspect its foundation, they peered through holes drilled down into the road and its supporting bed. Where there should have been concrete and aggregate, they saw only water. The entire foundation was gone. Our civil engineering professor "likes to say that this is when the Corps became 'scared green'" (30).

In their daily work, civil engineers, whose workplace brings them to an especially "physical closeness to the natural world," are more likely than, say, electronic engineers to be afraid in the presence of such magnificent forces (*CE* 23). Florman puts it this way:

> Beyond emergencies and disasters, through the environmental crisis of recent years, nature has demonstrated that she is indeed a living organism not to be tampered with unthinkingly. Nature's apparent passivity, like the repose of a languid mistress, obscures a mysterious and provocative energy. The engineer's new knowledge of nature's complexities is at once humbling and alluring. (*EP* 122)

Apart from fear, or maybe because of it, the very real consequences of failure—injury and death—haunt the engineer. It seems so often that in the process of making something better, engineers make another thing worse. Florman explains how in researching technology for an article on the Bicentennial, he came across a number of cases where injury was the result of invention. The development of saw mills led to cheap lumber and a preponderance of wood-framed houses, but all this brought about more and greater fires. Likewise, transportation efficiencies allowed houses to cluster together, but aggravated their flammability, as did an assortment of devices intended to increase comfort, such as "stoves, lamps, and warming pans" (*BT* 182). Yet one technological downfall begat another technological upswing. The increasing incidence of house fires led to the formation of volunteer fire brigades, and to buildings that bore fire-resistant materials, lightning rods, and so on.

In the same discussion, Florman points out how the invention of the steamboat in the 1800s brought about many deaths from boiler accidents: "From 1825 to 1830, forty-two recorded explosions killed upward of 270 persons." Then, in 1830, when more than fifty deaths resulted from a single boiler accident, the government was prompted "to take action," culminating in a safety standard for steam boilers in 1844. Likewise, bridge collapses in the latter part of that century were common, and a blemish on the technological marvel of the railroad. Civil engineers began to explore the problem and "eventually the safety of our bridges came to be taken for granted" (184).

Florman's point in this discussion is that technological advance has had its cost in lives lost. "Along with each triumph of mechanical genius came an inevitable portion of death and destruction" (184). Rather than give in to what must have been overwhelming discouragement, however, engineers persisted in finding technical fixes to problems brought about by technology. Florman call this a "pattern of progress/setback/renewed-creative-effort" (185).

McPhee finds a similar sequence playing out on the Mississippi. He traces the history of the region back to the early 1700s, to a time well before the Corps of Engineers started its handiwork there, to a time when the only levees that existed were built by the river—a process in which rivers deposit heavy sediment along their banks during floods, while letting lighter contents fan outward. Thus formed, the high ground along the Mississippi attracted home builders. Abutting the eastern shore of the Mississippi, New Orleans enjoyed protection from some, but not all, of the floods that regularly cycled down the river. Each time the levees would breach, though, the people of the city and the homeowners that dwelled atop the levees would pile on more dirt, each time assuring themselves they would stay dry come the next high water. Eventually, the levee grew tall enough that the flood waters would spill westward beyond the river's unbanked side, out onto the rest of Louisiana. Some time later, a levee rose along the river's far bank. The river was now confined. Later still, levees on both the east and west sides of the river lengthened, ultimately spanning a distance of a couple of hundred miles. Slowly, the lower Mississippi River was assuming the character of a pipeline and losing spillways onto its former flood plains.

With fewer places to expand into at times of high water, the water levels began seeping upward as the nineteenth century progressed. McPhee says, "The more the levees confined the river, the more destructive it became when they failed" (35). Florman calls this "progress/setback/ . . ." but *escalation* might be another name for it (*BT* 185). "Even at normal stages," McPhee writes, "the Mississippi was beginning to stand up like a large vein on the back of a hand. The river of the eighteen-seventies ran higher than it ever had before" (37). By 1920, the levees stood "six times as high as their earliest predecessors, but really no more effective." The levees, he continues,

> could be—and they would be—raised even higher. But in 1927 the results of the experiment at last came clear. The levees were helping to aggravate the problem they were meant to solve. With walls alone, one could only build an absurdly elevated aqueduct. (42)

The entire Mississippi delta, McPhee tells us, was created by the river:

> Southern Louisiana exists in its present form because the Mississippi River has jumped here and there within an arc about two hundred miles wide, like a pianist playing with one hand—frequently and radically changing course, surging over the left or the right bank to go off in utterly new directions. Always it is the river's purpose to get to the Gulf by the shortest and steepest gradient. (5)

Building levees was a way of demanding that the river behave in a manner suited to humanity's desires. By controlling the river, by leashing it, the levee builders encouraged the economies of New Orleans and Baton Rouge to prosper, to become gateways for bulk cargo and crude carriers making their way down or up river from points north or from overseas. Companies built plants between these two cities to take advantage of the fresh water and easy transportation; companies like "B. F. Goodrich, E. I. duPont, Union Carbide, Reynolds Metal, Shell, Mobil, Texaco, Exxon, Monsanto, Uniroyal, [and many others] . . . were there because of the river" (6). The problem was that the river did not want to stay put.

If you place your finger on the map of the Mississippi delta and trace the course of that fat blue line north from its mouth in the Gulf of Mexico, you'll wander past places such as Pilottown and Venice, Happy Jack and Sulpher, until, a hundred miles up you pass New Orleans, and another seventy five miles further still, Baton Rouge. Seventy five miles beyond there, give or take plenty depending on whether you trace the scenic route along the river's bends or the straight line between two points, you will come to a place that is essentially unmarked by any towns or such but recognizable by the fact that here the river becomes the westernmost border of the state bearing its same name. If your map maker has paid attention to details, a thin blue line juts away from the thick blue one representing the Mississippi; this line is more likely than not unnamed. If you change direction here and head almost due south you will pass Morgan City and wind up back in the Gulf of Mexico, in Atchafalaya Bay, one hundred and twenty miles west of where you started. The trip south will be shorter than the trip north was by one hundred and fifty miles.

It is this southbound course that is really the subject of McPhee's essay, and its title. The Atchafalaya River, in the natural sequence of things, wants the water of the Mississippi. It wants to divert the Mississippi's waters away from their present course past Baton Rouge and New Orleans. If the Atchafalaya were to have its way, in no time the Mississippi would be nothing more than a "tidal creek," Baton Rouge and New Orleans nothing more than the past (6). In the natural sequence of things, the river drains "to the Gulf by the shortest and steepest gradient" (4).

Obviously, the natural sequence cannot be allowed to happen. B. F. Goodrich, E. I. duPont, Union Carbide, and all the other companies there, along with New Orleans and

Baton Rouge, are too dependent upon the Mississippi to permit nature to have its way. The crux of McPhee's story is about the diversion of the Mississippi away from the Atchafalaya by a Corps of Engineers' control structure, the very same structure upon which our civil engineering professor walked and found to be vibrating like a freight train. The story is a real-world example of how engineers, as Florman says, respond to the will of the people.

One theme in particular seems to unite Florman's various writings and the McPhee essay. In tackling their subject from different perspectives, these two authors converge at a single spot. Florman writes on behalf of the profession of engineering with an obvious and unapologetic celebration of its achievements. McPhee approaches the subject as a less partial observer, albeit one with a clear understanding of science and technology, who has taken up the task of questioning the wisdom of certain engineering undertakings. If McPhee shows any bias at all, it is that he favors leaving nature be. But by the end of the essay, his reader has at least gained an understanding of the predicament faced by the Corps of Engineers in Louisiana. The Corps did not come upon the Mississippi delta in the eighteenth century and say, "Let's build a couple of cities in the path of this river." The Corps, instead, was called in, and much later too, long after a levee system had arisen, long after a maritime and shipping economy had come of age there. If the reader is not sympathetic to the Corps' plight by the end of the essay, as Florman would have it, then the reader is at least given an understanding of the technological issues that surround an undertaking as complex as the control of a river. In spite of much public criticism, the Corps works daily on the task of keeping an infrastructure afloat in the Mississippi delta.

This is not to say that engineers did not have a hand in developing the area to the point where the Corps had to be called in. In an especially evocative passage, McPhee reveals where the land that forms the delta comes from:

> In an average year, some two hundred million tons of sediment are in transport in the river. This is where the foreland Rockies go, the western Appalachians. Southern Louisiana is a very large lump of mountain butter, eight miles thick where it rests upon the continental shelf, half that under New Orleans, a mile and a third at Old River. It is the nature of unconsolidated sediments to compact, condense, and crustally sink. So the whole deltaic plain, a superhimalaya upside down, is to varying extents subsiding, as it has been for thousands of years. (57)

One of the very first engineering problems in the area was how to break through the "lump of mountain butter" that blocked the Mississippi's mouth, so that ships could enter the river. McPhee introduces James Eads, "probably the most brilliant engineer who has ever addressed his attention to the Mississippi River." From a career which had begun in his youth, when he salvaged along the river bottom using devices he had built himself, to the Civil War, when he "designed the first American ironclads," and beyond the war, when he "built the first permanent bridge across the main stem of the river south of the Missouri," Eads eventually set his mind upon the problem to which the day's top engineers had been long engaged. It was the "primal question of anadromous navigation: how to get into the river." All that sediment coming down river year after year simply dropped out once the water had blended with the placid gulf. To dredge would be monumental, both in scope and in the probability of failure. Without any support from taxes or foundations, Eads spent his own money realizing his "elegant idea [of] . . . parallel jetties in the river's mouth." Where the water formerly slowed as it moved onto the delta plain, now it would speed up, clearing sediment as it did and opening a channel to the sea (38).

In calling this solution "elegant," McPhee defers to Florman, who has been telling us all along that engineering is an act of passion and creativity. This is not something that we should readily believe when it comes from an engineer, but it is made much more believable when it comes from a disinterested writer. This is one of two instances in McPhee's story where he points out the beauty and elegance of engineering.

Earlier I had said that we would look at the beauty of physical objects first as we discussed civil engineering, and then we would turn our attention to the beauty of underlying form. Even though this might be a logical spot to talk about underlying form, since there probably isn't anything on the surface that is beautiful about two parallel rock walls, I am going to hold fast a bit and save that discussion for when we get to Pirsig. First, I want to call attention to McPhee's other reference to the beauty of engineering. This time, it is a statement he makes about physical beauty.

It turns out that the original control structure that was finished in 1963 and tested a decade later did not pass the test. So a second structure was built, its construction starting in 1983, after the Corps of Engineers spent time testing scale models of the river to understand just how the flow of water would behave around various control devices then being considered. The new structure was named "Old River Control Auxiliary Structure" to distinguish it from the original "Old River Control." Where the first one cost \$86 million, the second one cost \$300 million. McPhee writes, "The disproportion in these figures does, of course, reflect inflation, but to a much greater extent it reflects the price of lessons learned" (52).

McPhee does not elaborate upon the specifics of these lessons learned other than to say that the new structure incorporated "redundancies in its engineering in memory of '73" (53). He does take pains to describe the new structure, however:

> The Old River Auxiliary Control Structure is a rank of seven towers, each buff with a white crown. They are vertical on the upstream side, and they slope toward the Atchafalaya. Therefore, they resemble flying buttresses facing the Mississippi.

> The towers are separated by six arciform gates, convex to the Mississippi, and hinged in trunion blocks secured with steel to carom the force of the river into the core of the structure. (52)

The original control structure is described by McPhee as being nearly six-hundred feet long and incorporating "ten piers, framing eleven gates that could be lifted or dropped, opened or shut, like windows" (10). Where the original structure used piers, the new structure used "buttresses"; where the original structure used window-like gates, the new one used "hinged . . . arciform gates." The new control structure seems to be more elaborate, more carefully designed, but always with the goal of controlling the river. Had the old structure worked, would we come to think of it in the same loving terms that McPhee uses to describe the new one?

> Lifted by cables, these tainter gates, as they are called, are about as light and graceful as anything could be that has a composite weight of twenty-six hundred tons. Each of them is sixty-two feet wide. They are the strongest the Corps has ever designed and built. A work of engineering such as a Maillart bridge or a bridge by Christian Menn can outdo some other works of art, because it is not only a gift to the imagination but also structural in the matrix of the world. The auxiliary structure at Old River contains too many working components to be classed with such a bridge, but in grandeur and in profile it would not shame a pharaoh. (52)

While it may not be an unequivocal testament to the structure's beauty, it is enough to make the reader feel as if its designers had some desire to impart to it a gracefulness that also improved its underlying strength. Would it appear even more beautiful to the eye of an engineer?

Part of the structure's beauty is found in the learning that it represents. The first control structure was inadequate to cope with the force of the river. By following Florman's course of "progress/setback/renewed-creative-effort," (*BT* 185) the river engineers built a sandbox in scale where they played with the modeled down forces of the river. The new structure was a physical expression of their understanding of the river.

Florman says,

> The main goal has always been to understand the stuff of the universe, to consider problems based on human needs (or desires), to propose solutions, to test and select the best solution, and to follow through to a finished product (*EP* 113).

CHAPTER 4

STEEL ZEN

Having sampled a little of what Florman calls the civil engineer's "existential bond to the earth" in the writing of John McPhee, we are ready to follow Florman into the domain of the machine (*EP* 126). In this section we will look to the writing of Robert Pirsig in an attempt to find a literary expression of mechanical engineering there. Like Florman, but unlike Pirsig, I will try hard not "to wander too far into the realm of mystic experience" (141).

The publication of Pirsig's *Zen and the Art of Motorcycle Maintenance* actually preceded Florman's *The Existential Pleasures of Engineering* by a year. In many ways the books followed parallel tracks, the most obvious being the attempt at uniting technology and the humanities. At least two book reviewers, one writing for *Time* magazine and the other for *The New York Times*, mentioned this comparison in their reviews of Florman's book.

First, a summary of Florman's thoughts on the machine in poetry and literature is needed. Florman says, "Much creative writing about the machine is of limited interest to the engineer who seeks artistic interpretation of his own experience" (*EP* 130). After reading the passage he quotes from Black's *Machinery* ("Look long on an engine. It is sweet to the eyes."), I am disappointed when my "responsive chord" does not ring (133). When Florman goes looking for the expressiveness of engineering in poetry, he finds that the poets have had "limited success" (132).

Of course, a great deal of writing on the machine is embodied in the world of literature. Yet most of it, Florman says, is "hostile to the machine." When we look to the writers who celebrate the machine, "the problem is to find among them a quality of thought and expression that does not lapse into triteness and triviality" (130).

Florman has difficulty finding literature that reflects an engineer's love of machinery. Most of it, he says, sounds like this verse by Ebenezer Elliott:

> Engine of Watt! unrivall'd is thy sway.
> Compared with thine, what is the tyrant's power?
> His might destroys, while thine creates and saves.
> Thy triumphs live and grow, like fruit and flower. (qtd. in *EP* 130-31)

"More than two centuries of such doggerel have helped to confirm the machine's bad reputation among people of sensitivity" (131). Florman is able to find some redemption in a few lines from William Wordsworth. Florman recognizes that where many poets look for the surface beauty of machines, some, such as Rudyard Kipling and Walt Whitman, seek the "intrinsic beauty" in the machine. These poets attempt to find the underlying beauty of the machines they study, what he calls the machine's "dynamic elegance" (132). "The beauty of the machine is pure, like mathematics" (135).

This may be the same kind of beauty we discussed earlier in the elegant solution of Eads's Mississippi delta jetties. Or, take the lowly I-beam, for instance. Its appeal to an engineer comes from its high ratio of strength to weight. The I shape comes about not because engineers hold any affinity for this particular letter, but because of the underlying characteristics of the shape. An I-beam is used standing up: I, not H. The piece in the middle, called the web, resists bending almost as well as does a fully developed section, that which you would have if you filled in all the space between the top and bottom flanges. But how much more it would weigh if you did so! Stack enough of these filled beams together and a building collapses from its own crushing weight. Lighten the load carrying members, as an I-beam does, and a building scrapes the sky.

It is a similar inner beauty that Pirsig finds in machinery. One passage, in which the narrator is helping his artist friend, John, fix his loose handlebars, instills in an ordinary aluminum beer can the same kind of elegance that is hidden in an ordinary I-beam.

> When he brought his motorcycle over I got my wrenches out but then noticed that no amount of tightening would stop the slippage, because the ends of the collars were pinched shut.
>
> "You're going to have to shim those out," I said.
>
> "What's shim?"
>
> "It's a thin, flat strip of metal. You just slip it around the handlebar under the collar there and it will open up the collar to where you can tighten it again. You use shims like that to make adjustments in all kinds of machines."
>
> "Oh," he said. He was getting interested. "Good. Where do you buy them?"
>
> "I've got some right here," I said gleefully, holding up a can of beer in my hand.
>
> "He didn't understand for a moment. Then he said, "*What*, the *can*?"
>
> "Sure," I said, "best shim stock in the world."
>
> I thought this was pretty clever myself. Save him a trip to God knows where to get shim stock. Save him time. Save him money.
>
> But to my surprise he didn't see the cleverness of this at all. In fact he got noticeably haughty about the whole thing. Pretty soon he was dodging and filling with all kinds of excuses and, before I realized what his real attitude was, we had decided to not to fix the handlebars after all.
>
> As far as I know those handlebars are still loose. And I believe now that he was actually offended at the time. I had the *nerve* to propose repair of his new eighteen-hundred dollar BMW, the pride of a half-century of German mechanical finesse, with a piece of old *beer* can!
>
> *Ach, du lieber!*
>
> Since then we have had very few conversations about motorcycle maintenance. None, now that I think of it.
>
> You push it any further and suddenly you are angry, without knowing why.
>
> I should say, to explain this, that beer-can aluminum is soft and sticky, as metals go. Perfect for the application. Aluminum doesn't oxidize in wet weather—or, more precisely, it always has a thin layer of oxide that prevents any further oxidation. Also perfect.
>
> In other words, any *true* German mechanic, with a half-century of mechanical finesse behind him, would have concluded that this particular solution to this particular technical problem was *perfect*.
>
> For a while I thought what I *should* have done was sneak over to the workbench, cut a shim from the beer can, remove the printing and then come back and tell him we were in luck, it was the last one I had, specially imported from Germany. That would have done it. A special shim from the private stock of Baron Alfred Krupp, who had to sell it at a great sacrifice. Then he would have gone gaga over it. (57-58)

On the surface the beer-can shim is ugly—the kind of thing you would find on the side of the road. Beyond its surface, the beer can turns out to be "perfect" for the task at hand, owing to its availability, its low cost, its durability, and its malleability. The German mechanic sees it in this light, whereas the artist sees it for its surface aspect. This is Florman's argument with the writers looking for the machine's appeal. Florman says, "The machine, as experienced by the engineer, is a model of dynamic elegance—not a copy of a horse or a dragon as some poets have tried to depict it, but in its own essence" (*EP* 132). Notice how Pirsig's narrator, to imbue the beer-can shim with the necessary appeal to his artist friend, needs to dress it up with a tale of origin. When viewed in this way, as a shim crafted specifically for correcting the fit of assembled machine parts, the beer-can shim loses its ugliness.

Something else is revealed in Pirsig's passage, something that becomes a major theme in his book. The motorcycle mechanic reflects a "half century of mechanical finesse." We envision the mechanic assembling precision machinery with a great deal of care, working materials to close tolerances, measuring and checking for fits and clearances. The mechanic cares about the machine. And, Pirsig's narrator, by fixing the handlebar, sees his efforts as a continuation of this caring.

Florman points out others who care about machinery. He quotes Richard McKenna's *The Sand Pebbles* ("Jake Holman loved machinery the way some other men loved God, women and their country.") and Anne Morrow Lindbergh's thoughts on the comfort of her airplane cockpit:

> Not only the tools I was working with, the transmitter and receiver, the key and the antenna reel; but even the small irrelevant objects on the side of the fuselage, the little black hooded light, its face now turned away from me, the shining arm and knob of the second throttle, the bright switches and handles, the colored wires and copper pipes: all gave me, in a strange sense, as much pleasure as my familiar books and pictures might at home.(qtd. in *EP* 136-37)

In reading Pirsig, however, we discover why caring about everyday things like machine parts should matter. He takes us below the surface appeal of objects, and describes why precision is important in mechanical assembly. The thoroughness Pirsig directs toward ordinary mechanical parts, as in the following passage, forces us to reconsider whether a love for machinery is so odd.

> A "mechanic's feel" implies not only an understanding for the elasticity of metal but for its softness. The insides of a motorcycle contain surfaces that are precise in some cases to as little as one ten-thousandth of an inch. If you drop them or get dirt on them or scratch them or bang them with a hammer they'll lose that precision. It's important to understand that the metal *behind* the surfaces can normally take great shock and stress but that the surfaces themselves cannot. When handling precision parts that are stuck or difficult to manipulate, a person with mechanic's feel will avoid damaging the surfaces and work with his tools on the nonprecision surfaces of the same part whenever possible. If he must work on the surfaces themselves, he'll always use softer surfaces to work them with. Brass hammers, plastic hammers, wood hammers, rubber hammers and lead hammers are all available for this work. Use them. Vise jaws can be fitted with plastic and copper and lead faces. Use these too. Handle precision parts gently. You'll never be sorry. If you have a tendency to bang things around, take more time and try to develop a little more respect for the accomplishment that a precision part represents. (324)

This passage turns out to be a popular one. Robert Adams, reviewing Pirsig's book, compared the passage to another one about reverence from Kerouac's *On the Road.* Adams writes, "Kerouac bangs the English language around. He is incapable of a pair of sentences like 'Use them,' and 'Use these too'" (23). The passage is quoted again in a writer's manual by Barnett and Stubbs (127). It is surprising that while Florman does quote Pirsig in *The Existential Pleasures of Engineering*, it is not this particular selection. Florman tells us that it was Homer, after all, who wrote with a heavy emphasis about building things and working with materials. Florman points out Homer's description of the manufacture of Achilles' shield and the construction of Odysseus's raft. "We emerge from the world of Homer drunk with the feel of metals, woods and fabrics" (*EP* 109).

Pirsig's description of "mechanic's feel" seems a fitting accompaniment to the delight with materials that Florman expresses. It also exemplifies the earthy appeal of engineering of which Florman is so fond.

But what about engineering? Pirsig is talking about mechanics here, not engineering. Pirsig holds engineering and mechanics in a much tighter association than Florman does. To be sure, Florman makes a point of drawing a sharp distinction between engineering and mechanics:

> Here I had better interject very quickly the reminder that professional engineers are not to be confused with mechanics or technicians. Yet, in considering the emotional relationship of man to machine, the engineer shares a common bond with every fellow being who works with machines, understands them, and is entranced by them. (*EP* 136)

Pirsig, in fact, sees mechanics as the ideal entryway for people wishing to the join the profession. He describes the imagined journey of one college dropout. After bouncing around for a while, the dropout takes a job as a mechanic, joining the "school of hard knocks." But he is a smart kid, and is eventually bored by the drudgery of shop work:

> His creative intelligence, stifled by too much theory and too many grades in college, would now become reawakened by the boredom of the shop. Thousands of hours of frustrating mechanical problems would have made him more interested in machine design. He would like to design machinery himself. He'd think he could do a better job. He would try modifying a few engines, meet with success, look for more success, but feel blocked because he didn't have the theoretical information. He would discover that when before he felt stupid because of his lack of interest in theoretical information, he'd now find a branch of theoretical information which he'd have a lot of respect for, namely, mechanical engineering. (196-97)

In some ways this passage mirrors what Florman says about the humanities. One of his big issues is the addition of humanities into the engineering curriculum. Whereas Pirsig's mechanic feels "stupid" because he lacks necessary technical information, Florman's technologists feel awkward and left out because they lack necessary cultural knowledge, and, as a consequence, social skills. A section of *The Civilized Engineer* is devoted to remedying this.

Florman tells us that although "engineers have performed miracles" in their technological exploits, it has been the "increasing technical content" of engineering education that has almost excluded the humanities, and shortchanged engineers of a broad, "wide-ranging" education, so that they are rendered "less 'cultured'" (*CE* 171). But, Florman continues, "It is not just a matter of superficial refinement, equipping oneself for 'parlor conversation.' It comes down to recognizing that words and ideas are worthy of respect" (183). Just as Pirsig sees engineering education as a way of pulling a mechanic out of the garage, Florman sees liberal arts education as a way of pulling engineers away from "dull, pedestrian career paths" (224).

This is not the only place where Florman's and Pirsig's writing align. "Every engineer has experienced the comfort that comes with total absorption in a mechanical environment," Florman says. Working in the moment, all distractions are silenced. "This state of mind is scorned by many humanists, but in a way it is similar to the comfortable seclusion one feels when listening to a carefully constructed musical composition of the classical period" (EP 137). Pirsig describes mechanics as they might be seen by an "untrained observer" who

> will see only physical labor and often get the idea that physical labor is mainly what the mechanic does. Actually the physical labor is the smallest and easiest part of what the mechanic does. By far the greatest part of his work is careful observation and precise thinking. That is why mechanics sometimes seem so taciturn and withdrawn when performing tests. They don't like it when you talk to them because they are concentrating on mental images, hierarchies, and not really looking at you or the physical motorcycle at all. (111)

Later, Pirsig describes the same "total absorption" in a different context:

> "Actually this idea isn't so strange," I continue. "Sometime look at a novice workman or a bad workman and compare his expression with that of a craftsman whose work you know is excellent and you'll see the difference. The craftsman

> isn't ever following a single line of instruction. He's making decisions as he goes along. For that reason he'll be absorbed and attentive to what he's doing even though he doesn't deliberately contrive this. His motions and the machine are in a kind of harmony. He isn't following any set of written instructions because the nature of the material at hand determines his thoughts and motions, which simultaneously change the nature of the material at hand. The material and his thoughts are changing together in a progression of changes until his mind's at rest at the same time the material's right."
>
> "Sounds like art," the instructor says.
>
> "Well, it *is* art," I say. "This divorce of art from technology is completely unnatural." (167)

What is so absorbing to this mechanic, to this craftsman? What puts them so totally in the moment? Whatever it is, it clearly follows the kind of path Florman envisions when he calls the pleasures of engineering "existential." The craftsman Pirsig describes must get pleasure from his actions as the material and the method changes in a dance with one another. Beyond this pleasure, though, we begin to appreciate the level of concentration in the work, much more than mere wrench-turning, which might account for the serious posture these workers assume. If pleasure is involved in a thing done right, though, it is not a giddy, nervous joy but rather a quiet contentment that arises from a knotty problem untied. Yet, if technical work produces so much joy, why is it that mechanics and engineers seem so emotionally detached? Pirsig attributes their detachment to the nature of the work which requires that their egos be left at the door:

> If you know enough mechanics to think of them as a group, and your observations coincide with mine, I think you'll agree that mechanics tend to be rather modest and quiet. There are exceptions, but generally if they're not quiet and modest at first, the work seems to make them that way. And skeptical. Attentive, but skeptical. But not egoistic. There's no way to bull—— your way into looking good on a mechanical repair job, except with someone who doesn't know what you're doing. (314-15)

Reading this passage brings to mind Fred Bayley, McPhee's "contemplative" engineer (25). Bayley, like many engineers, you would expect to be "modest and quiet," considering that for even the most cautious engineer projects can end in failure. Given the possibility of such an outcome, it is understandable why so many engineers might lack a sense of humor. Florman finds skepticism and seriousness to be traits that are also common among engineers:

> The trouble doubtless begins with the precision inherent in engineering work. Technical problems usually have correct answers, or at least optimal solutions. Engineers learn to be suspicious of whimsy, caprice, and absurdity, the very stuff of humor, but dangerous notions when public safety is a consideration. (*IE* 149)

Elsewhere, Florman puts it this way:

> Speaking of being dull, there can be no denying that the engineering view is essentially serious. Engineering work involves logic and precision. Unfortunately, this can lead to coldness and austerity. Engineers have a reputation for being humorless, and I fear this reputation is not entirely unfounded. There is no sense pretending that engineering is fun and games (although it often *is* fun), or that engineers are by nature jolly. (*CE* 75)

It is here that Pirsig's and Florman's views diverge somewhat. Pirsig believes that this somber, reflective view is what is needed by a society out of balance. In caring about one's work, no matter how meaningless or dull the work might seem, Pirsig figures that the quality reflected in work done well would "fan out like waves," such that "the person who sees it feels a little better because of it, and is likely to pass that feeling on to others." Ultimately, he believes "this is how any further improvement of the world will be done: by individuals making Quality decisions and that's all" (357). Pirsig wants to apply the mechanic's view to the world in hopes of making it a better place.

Florman, in contrast, sees the mechanic's view as limiting for engineers who seek work that is more than purely technical. Florman thinks engineers should develop a sense of humor, and "join in the drinking and the dancing" that is a part of life (*EP* 152). "People, unlike machines, are not generally logical, rational, and predictable," he says, explaining why it is that engineers have failed to perform well in politics. He mentions John Sununu, whose career took him from a Ph.D. from MIT, to an associate dean's position at Tufts, then on to several political offices in New Hampshire which culminated in that state's governorship, and then to President George Bush's team as the White House Chief of Staff. His fall from there was in part due to his exhibiting "little patience for human idiosyncracies [*sic*], and little appreciation of the need for political give and take." President Jimmy Carter, a former nuclear engineer, provides a second example of the engineer's inadequacies in the world of politics, and President Herbert Hoover, who was elected as "The Great Engineer," a third. Carter's failure to win re-election was blamed partly on his engineer's mindset, and Hoover's, on his "insensitive" manner. Thus, "we reach the origins of the engineer-in-politics story, a rather melancholy American chronicle" (*IE* 140).

Just as soon as Pirsig's and Florman's views diverge, they converge again. Florman quotes the columnist Tom Wicker speaking about how Carter used "an engineer's approach of devising 'comprehensive' programs on this subject or that, but repeatedly failed to mobilize public opinion in their support" (141). Pirsig writes, "I don't want to have any more enthusiasm for big programs full of social planning for big masses of people that leave individual Quality out" (358).

Perhaps engineers don't make the best politicians, but that's not to say they lack emotion. Earlier, I talked about how engineers, as well as mechanics, can come to care about machinery. The care that Pirsig discusses, which comes from maintaining an old motorcycle, seems to correspond with what Florman says about machines as they age. "Machines tend to age gracefully," Florman writes, reminding us how locomotives have come to stand for an almost romantic remembrance to many admirers of yesteryear. "Once regarded as an ugly monster, [the locomotive's] beauty and charm are now widely acclaimed." Quoting from Siegfried Sassoon ("That train's quite like an old familiar friend, one feels.") and Antoine de Saint Exupéry ("What is it today for the villager except a humble friend who calls every evening at six?"), Florman brings to mind Pirsig's description of his cycle (*EP* 135):

> The machine itself receives some of the same feelings. With over 27,000 on it it's getting to be something of a high-miler, an old-timer, although there are plenty of older ones running. But over the miles, and I think most cyclists will agree with this, you pick up certain feelings about an individual machine that are unique for that one individual machine and no other. A friend who owns a cycle of the same make, model and even same year brought it over for repair, and when I test rode it afterward it was hard to believe it came from the same factory years ago. You could see that long ago it had settled into its own kind of feel and ride and sound, completely different from mine. No worse, but different. (49)

The passage is reminiscent of sailors describing favorite boats, or bibliophiles discussing rare first editions. Some kind of emotional bond has developed over the years between this man and this machine, which, through the years of maintenance and repair, has cemented what seems to be a friendship that has its allegory in the act of turning a house into a home. Pirsig continues:

> I suppose you could call that a personality. Each machine *has* its own, unique personality which probably could be defined as the intuitive sum total of everything you know and feel about it. This personality constantly changes, usually for the worse, but sometimes surprisingly for the better, and it is this personality that is the real object of motorcycle maintenance. The new ones start out as good-looking strangers and, depending on how they are treated, degenerate rapidly into bad-acting grouches or even cripples, or else turn into healthy, good-natured, long-lasting friends. (49)

Maybe, then, it's not that engineers are uncaring enough to excel at politics; maybe they care too much. Carter was known for his refusal to delegate work to his staff, and the long hours he kept because of it. That would be typical of engineers, whose extreme attention to detail makes it difficult for them to break into management positions. It all goes to not being able to sleep at night, knowing, perhaps, that you had to rely on others to make sure the rivets were installed correctly in a certain bridge girder, or knowing that the people balancing a steam turbine could cause injury or death if they miscalculate the correction weights. To get that tied up in the caring for a machine ought to mean that when it comes to people, engineers are even more caring than average. Maybe Carter demonstrates this in his work with Habitat for Humanity.

I keep coming off the main topic of this chapter, which is supposed to be about the beauty that lies below the surface of engineered items, such as the jetties we learned about in the previous section. Before we get too far along with comparing what Florman says about the character of engineers with what Pirsig says about the character of mechanics, I should try to connect what McPhee calls an "elegant solution" to what Pirsig defines as "classical beauty." Doing so, maybe I can amplify Florman's thoughts on the creativity inherent in engineering. And as we move to the view of beauty that lies beneath the surface of physical things, we will be better prepared to enter the world of abstract beauty, the world of electronics and logic.

The odd thing about really elegant engineering solutions is how simple, how direct—how obvious—they look when they are finally put in place. Eads's jetties, for instance. Just pile up a bunch of rocks to mimic the river bank. No one else could see it, though. The idea itself was not sufficiently convincing to get government backing. Pirsig says, "The solutions are all simple—after you have arrived at them. But they're simple only when you know already what they are" (287).

Pirsig has a few thoughts on the value of the scientific method for coming up with solutions:

> It's good for seeing where you've been. It's good for testing the truth of what you think you know, but it can't tell you where you *ought* to go, unless where you ought to go is a continuation of where you were going in the past. Creativity, originality, inventiveness, intuition, imagination—"unstuckness," in other words—are completely outside its domain. (280)

Engineering is very much a creative activity. Florman says, "An essential element of the profession of engineering is the concept of *creativity*" (*EP* 142). Eads couldn't simply follow some set of rules, or some logical sequence of events, to come up with his idea for opening the mouth of the Mississippi. The solution he uncovered had never been done before. Yet, he was not free to try just any old thing either—he was bound by the physical laws of nature. How did he come up with the idea? Maybe inspiration had something to do with it.

Nikola Tesla provides Florman with an example of this kind of inspiration. Tesla was determined to find a substitute for the brushes that were used in the direct-current electric motors of his day. The brushes were used to compensate for the fact that the alternating electric current would change direction once every cycle, making it impossible for an electric motor to spin in only one direction without them. The brushes, contacting the motor rotor, would wear, requiring frequent service. Tesla envisioned a motor that operated on alternating current without needing brushes. He designed an induction motor whose rotor would chase a rotating electromagnetic field around. It was a breakthrough that had no precedent in the thinking of his day. But, as Florman points out, it was a passage in Goethe's *Faust* that supplied Tesla with the metaphor he needed to change his thinking:

> The sun sinks; the day is done.
> The heavenly orb hastens to nurture life elsewhere.
> Alas, no wings lift me from earth.
> To strive always to follow . . . ! (qtd. in *CE* 188)

The solution was easy once Tesla had discovered it. Pirsig would probably say, however, that no amount of scientific method would have uncovered it—the solution was not a "continuation" in the direction that the thinking up until then had been headed.

At any rate, Tesla's solution to his problem, like Eads's solution to his, was elegant because it represented a new understanding of the world. This understanding is what

Pirsig refers to when he makes a distinction between "romantic" and "classic" modes of thought.

> A classical understanding sees the world primarily as underlying form itself. A romantic understanding sees it primarily in terms of its immediate appearance. If you were to show an engine or a mechanical drawing or an electrical schematic to a romantic it is unlikely he would see much of interest in it. It has no appeal because the reality he sees is its surface. Dull, complex lists of names, lines and numbers. Nothing interesting. But if you were to show the same blueprint or schematic or give the same description to a classical person he might look at it and then become fascinated by it because he sees that within the lines and shapes and symbols is a tremendous richness of underlying form. (73)

The journey into engineering exposes the engineering student to the "richness of underlying form." Learning about the forces of nature and the structures necessary to manage them, the student engineer finds it increasingly difficult to engage the world through its surfaces alone. For the engineer trained in "classical understanding," though, there is plenty of beauty and elegance in the world of underlying form, and plenty of creativity there too. We've found beauty on the surface of things (McPhee's description of the Old River Auxiliary Control Structure) and elegance in underlying form (Eads's parallel jetties). As for underlying beauty, Pirsig provides a description of how it might be manifest in a motorcycle:

> Although surface ugliness is often found in the classic mode of understanding it is not inherent in it. There is a classic esthetic which romantics often miss because of its subtlety. The classic style is straightforward, unadorned, unemotional, economical and carefully proportioned. Its purpose is not to inspire emotionally, but to bring order out of chaos and make the unknown known. It is not an esthetically free and unnatural style. It is esthetically restrained. Everything is under control. Its value is measured in terms of the skill with which this control is maintained. (74)

The shapes of the parts that compose the motorcycle engine, for instance, exist because they are the shapes that achieve the best compromise of strength, weight, manufacturability, cost, and reliability needed "to bring order out of chaos." The chaos results from the explosion that takes place when gasoline vapors ignite. The very purpose of the motorcycle engine is to control this energy release. Pirsig continues:

> The enormous forces of heat and explosive pressure inside this engine can only be controlled through the kind of precision these instruments give. When each explosion takes place it drives a connecting rod onto the crankshaft with a surface pressure of many tons per square inch. If the fit of the rod to the crankshaft is precise the explosion force will be transferred smoothly and the metal will be able to stand it. But if the fit is loose by a distance of only a few thousandths of an inch the force will be delivered suddenly, like a hammer blow, and the rod, bearing and crankshaft surface will soon be pounded flat. (99)

The elegance that accompanies a successful method of controlling nature, to borrow McPhee's title, may not show up at the surface. What is ugly to the person who doesn't understand the works may be beautiful to the person who does. The field of industrial design exists, to some extent, so that beauty might be imparted to elegant engineering solutions that on their surfaces are ugly.

The obvious example of this comes from Pirsig's book. The narrator's friend John owns a BMW motorcycle. These machines are legendary for their reliability, smooth ride, quiet running, longevity—and ugliness. These characteristics are due in large part to the design of the BMW engine. In motorcyclist's parlance the BMW engine is called a "boxer twin;" technically speaking, it's a horizontally opposed twin. What's immediately odd about these bikes is the single, mammoth, finned cylinder that juts out horizontally from either side of the engine crankcase. These two cylinders seem to lie in a plane whose direction goes opposite to the direction everything is supposed to go on a motorcycle. If the bike was an airplane, these two cylinders would be its wings. But it's not. And they're not. Instead of a sleek machine, these cylinders add a whole other perspective to the cycle. I don't know of one person who, coming upon such a motorcycle for the first time, hasn't thought it ugly, funny looking, or weird.

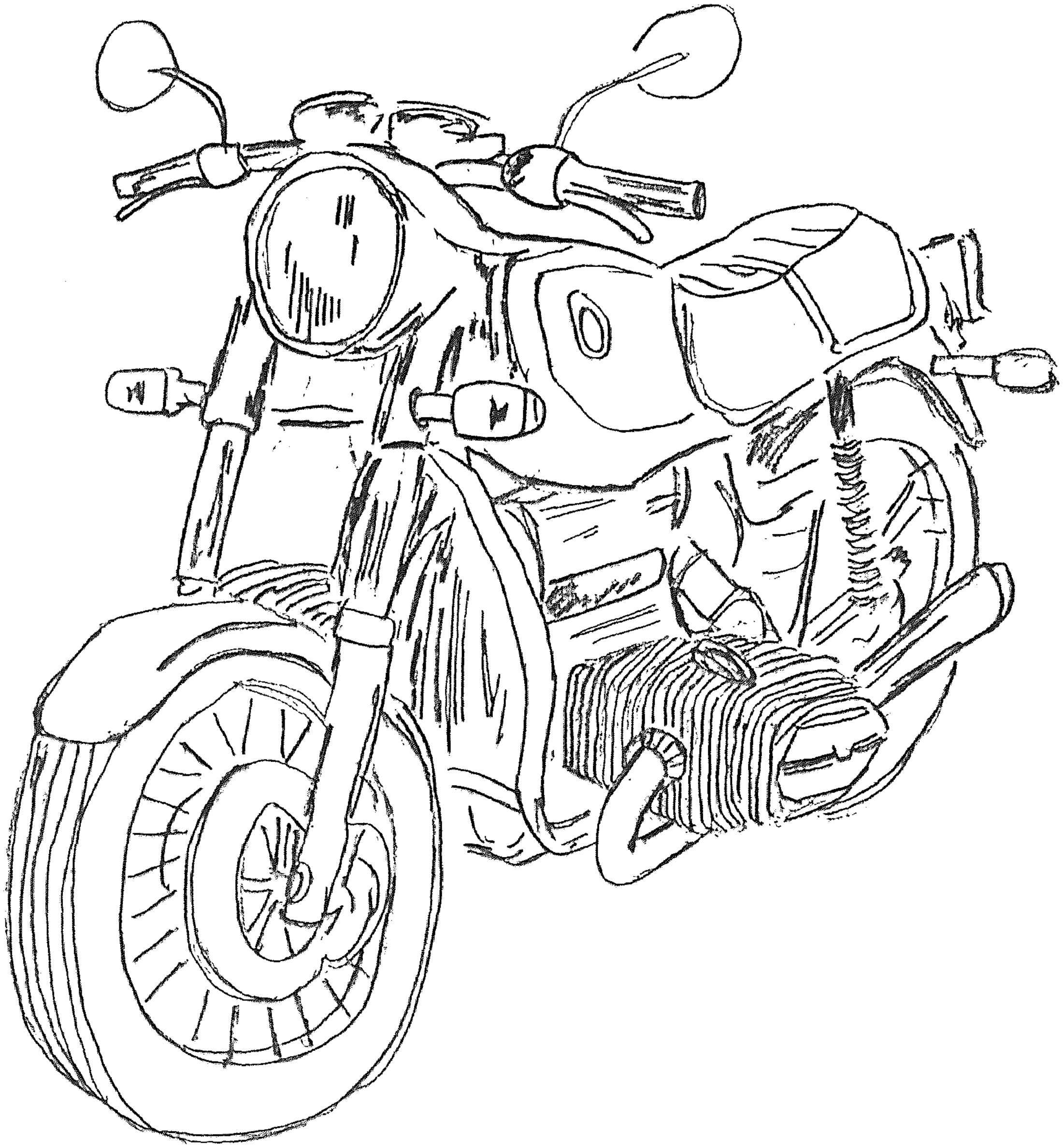

Fig. 1. BMW Boxer Twin

Aesthetics had nothing to do with this bike's design. If visually aesthetic appeal was the goal, you would be inclined to buy a fully dressed Harley-Davidson and put up with the fatigue that comes along after miles of low-frequency vibration has completely sedated your backside. That sort of discomfort does not exist on a BMW. This is because the funny looking engine turns out to employ one of the best techniques for smoothing vibration. Any engine vibrates as a consequence of the piston moving back and forth inside the cylinder. The piston moves towards the top of the cylinder, compressing a mixture of gasoline vapor and air. The spark plug fires, the mixture of gasoline and air explodes, and the piston is driven back towards the bottom of the cylinder. This is happening anywhere from hundreds to thousands of times per minute on a motorcycle, depending on whether it is idling in a traffic jam or roaring along the Yellowhead Highway up near its redline speed.

Engine engineers come up with all kinds of ways to dampen this vibration, but mostly it comes in the form of counterweights that balance the force of the piston as it paces back and forth within the cylinder. Motorcycle engines are configured with one cylinder, two cylinders, or four cylinders, although arrangements of three cylinders or even six are not unknown. On multiple cylinder engines, some vibration can be taken up through careful arrangement of the cylinders. Hold your outstretched index and middle fingers, for example, in the shape of a **V** in front of your face, like a peace sign. Move your hand from left to right and you've described the arrangement of the Harley-Davidson vertical twin as it is driven past you, while you stand at the side of the road. Same finger and hand position, but now move your hand toward your face, and you are seeing another vertical twin, this time a Moto Guzzi, coming at you. These two are unusual configurations. Many motorcycles coming at you would have their cylinders pointing straight up in a bank from one to four (or more) cylinders wide.

Unless you are double jointed, it is difficult to envision the BMW boxer twin with finger exercises. To do so, you would have to break your index finger and lay it out so that it lined up with your middle finger while pointing in the opposite direction. Uncomfortable for fingers, yes, but quite comfortable for motorcycle engines. The BMW engine's two cylinders lie in a straight line. When one piston is traveling out toward the outboard end of its cylinder, the other piston is moving in the opposite direction toward the outboard end of its cylinder. Whatever one piston is doing in the horizontally opposed twin, the other is doing the opposite. A natural counterbalance, you say. Yes, and one of the reasons that the cylinders on a BMW stick out like afterthoughts.

Another benefit of this arrangement is the unsurpassed cooling achieved by putting both cylinders way out in the air stream. Heat comes from compression of the air-fuel mixture in the cylinder, and by way of the spark-ignited explosion as well. Many motorcycle engines are air cooled, dispensing with the water-filled radiator systems found in most cars. That is what all those fins on the motorcycle cylinders do—they radiate heat. At idle, the engine is not working hard, and the fins dissipate enough heat to prevent the engine parts, the very same ones that Pirsig told us a moment ago depend on precision fits, from expanding too much and seizing. On the highway, the engine is doing much more work and generating much more heat. But there, the movement of the machine brings a constant wind of cooling air past the fins. It is easy to imagine the Harley-Davidson engine, with its upright V-twin design, having a difficult time getting enough air past the rear cylinder. Or consider the other designs whose cylinders stick straight up in banks of two, three, or four. Those cylinders directly behind the front wheel are starving for air. Not so on the BMW boxer twin, though.

The BMW engine puts a lot of metal down low. Unlike other designs where the cylinders ride up high, the BMW engine keeps a significant portion of the engine weight close to the ground. This is important because a motorcycle is steered by leaning (just like a bicycle is). The lower the cycle's center of gravity—the imaginary point from which if the bike were suspended it would remain perfectly balanced—the better the cycle can right itself after a hard lean. A low center of gravity counters the rider's lean. On top-heavy cycles, high centers of gravity can actually work toward toppling the bike rather than righting it.

A final benefit of the BMW design has to do with safety. Laying a motorcycle down is something that many riders come close to at some point in their riding careers. There are actual techniques that can help to raise the probability of surviving a bike crash unscathed, at least in the 30 mph range. At 60 mph, survival is less probable. When a rider drops a bike, most cycles will tend to crush the rider's leg between engine and road. Because its cylinders stick so far out, a BMW that has gone down can skid along the road on three points—the two tires and the engine cylinder—providing a substantially higher degree of protection to the rider in low-speed crashes.

So the BMW engine is a perfect example of an elegant design that has little surface appeal. Recognizing that aesthetics plays a big part in many cyclists' choice of steeds, BMW designers started to streamline their boxer engine with fairings and cowlings, in an effort to conceal its ugliness. But many BMW owners came to realize that there really was a great deal of beauty lying below the surface of things.

Another example of sub-surface beauty, transcending surface ugliness, comes from the field of bridge engineering. The Forth Bridge, which spans the Firth of Forth in Scotland, strikes first-time viewers with the same kind of response given to BMW

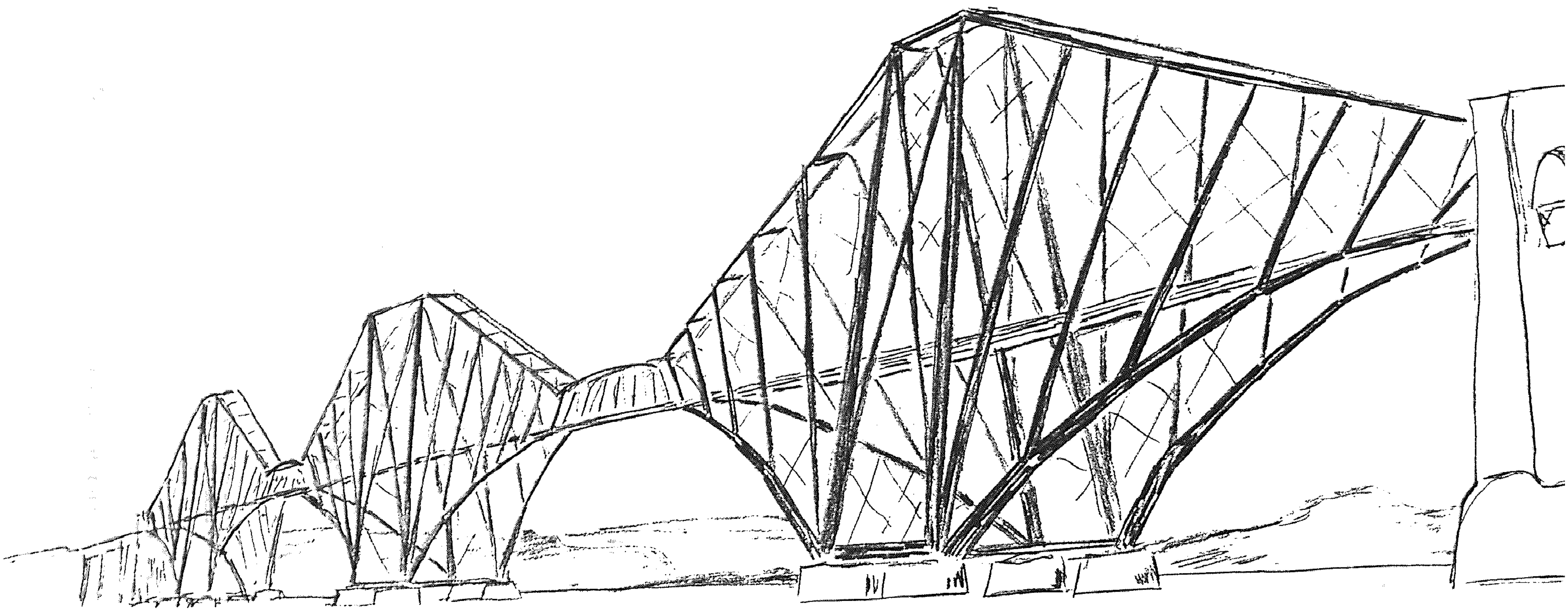

Fig. 2. The Forth Bridge Crossing the Firth of Forth, Scotland

engines. If they don't shrink back in terror, viewers can often be heard giggling among whispers of "Why'd they do that?" This bridge was completed in 1890 and was the first all steel bridge to span a long distance (1710 feet). What is most striking about its design is what Judith Dupré calls an "elaborate, visually dense configuration of ties and struts brac[ing] the giant tubes, 12 feet in diameter, that rise 342 feet from the circular caissons at the water line" (59). Its cantilevered design rose up from the bridge-building techniques of ancient Asia, while its steel work was the latest in building materials of the day, having just been legalized in Britain for construction purposes.

Unlike the gossamer appearance of modern suspension bridges, the visual bulk of the Forth Bridge gives the impression that it was overbuilt. But its construction started shortly after a nearby bridge spanning the Firth of Tay "collapsed in a gale while a train was crossing, killing more than seventy people" (59). The builders of the Forth Bridge took this tragedy into account, designing their bridge to withstand almost a fivefold increase in wind loading over what the Tay could tolerate.

The Forth Bridge employs three imposing cantilevers, supporting two smaller spans between them. Such is the nature of a cantilevered structure: It uses a great deal of structure at its anchor points to hold up a comparatively small structure at its unsupported ends. The cantilevers were built out from their centers in a symmetrical fashion, taking advantage of the balancing power of equal masses. Dupré continues:

> Much ado was made of the design among the general public: its safety, its cost, and above all, its appearance. Like the Eiffel Tower, the Forth Bridge is pure structure—having no unnecessary parts—and endures as both a work of art and an icon to man's mastery of the power of the wind. (59)

I would like to close this chapter with a passage from Pirsig that nicely ties together Mark Twain's ideas about beauty, the Mississippi River of John McPhee, and the thought that for beauty to exist in a thing's underlying form may mean that the beauty at its surface must vanish.

> When analytic thought, the knife, is applied to experience, something is always killed in the process. That is fairly well understood, at least in the arts. Mark Twain's experience comes to mind, in which, after he had mastered the analytic knowledge needed to pilot the Mississippi River, he discovered that the river had lost its beauty. Something *is* always killed. But what is less noticed in the arts—something is always created too. (83-84)

To discover that which is created is to discover the beauty in the abstract, to see things in the same way as does the engineering student we talked about a few pages back. To see the elegance below the surface of things is to shut one's eyes forever to mere surface characteristics—a kind of one-way trip. Consider in part the life cycle of a mosquito. From a mat of eggs stuck on the wet side of a pond's surface, larval hatchlings flutter about in a world of water, feeding and growing, unaware of the part that the air above will play in their future. One day, metamorphosis. Fleeing their larval lives, the mosquitoes push through the pond's skin into another world. From then on, no matter how hard they try, the mosquitoes simply cannot dive back below the surface. Theirs, too, is a one-way trip. Surface tension creates so impenetrable a barrier that water might as well be ice. We see it as miraculous that these bugs can walk on water. For them, however, it is immersion that is the miracle.

CHAPTER 5

SILICON SOUL

Tracy Kidder's *The Soul of a New Machine* was heralded by Florman as the book which exactly fulfilled his hoped-for literature of technology. Florman praised the book in *The New York Times Book Review* (August 23, 1981), and later incorporated the essay into *The Introspective Engineer*. A few lines reveal his pleasure with Kidder's book:

> In the Introduction of the *John McPhee Reader*, William L. Howarth insists that although most of Mr. McPhee's work is called "non-fiction" it should more properly be called "Literature." This is exactly the way I feel about Mr. Kidder's *The Soul of a New Machine*, and I believe Aldous Huxley—who looked forward to the coming of a worthy literature of science and technology—would agree. (18)

Although it is in this work, more than in the other two we have studied, that Florman finds the passion in engineering, we can't really count on Florman to be our guide as we seek out the beauty of electronic and software engineering. This is because computer engineering was not covered to the extent that civil and mechanical engineering were in *The Existential Pleasures of Engineering*, at least not from the perspective of beauty. By the time *The Soul of a New Machine* was published, Florman had moved on to other terrain. But thanks to his efforts, we can continue on alone. Florman does have a few things to say about computers, however, which we should discuss before starting with Kidder's book. Also, much of the Kidder book provides examples of the engineering personality just as the other two have, so we will look at some of these examples while we search for the beauty of computers.

A civil engineer, Florman ties a great deal of the profession to the relationship between humans and nature. From the earliest exploits of the lighthouse and bridge builders, to the later designs of the machinery builders, and on to the works of electrical and chemical engineers, a fundamental chain has linked engineering to nature. With software engineering this link yields a little, relaxing its tie to things natural. "In the so-called electronic era," Florman says "the engineer's physical closeness to the natural world has diminished" (*CE* 23). Of course, computer software is not that far removed from nature, since it runs on machines that are etched out of silicon and copper. In this sense software engineers are controlling nature too. To extend this reasoning, much software is devoted to making simulations of all sorts of natural forces and artificial phenomena, from the weather and the atmosphere, to the forces on an airplane wing or a rocket, to the variability of the stock market. So, the software engineer is in a sense recreating nature in a box, and may be, on second thought, as closely allied with nature as are the other, older branches of the engineering tree. After all, wasn't it nature-in-a-box that those civil engineers were doing when they put their Mississippi River model in a sandbox?

One does get the feeling sometimes that software engineers—like kids thinking that it was their generation and not their parents' that invented sex—think their work is the important stuff, and the work which came before, such as that of mechanical engineers who discovered how to generate electricity from motion, or that of electrical engineers who learned how to control and transform it, or that of civil engineers who constructed the towers to hold the wires used to transmit it, somehow does not qualify as high technology. In his review of Steven Levy's *Insanely Great: The Life and Times of Macintosh*, Florman responds to this attitude.

> In all of this, Mr. Levy stresses the role of the freewheeling conceptualizers. He calls metaphor "the key to making computers comprehensible," scarcely mentioning the hardware that lies within. He celebrates eccentricity and whimsy, observing that the members of the Macintosh team thought of conventional engineers as "bozos." He doesn't bother to note that such bozos invented and developed the transistor (1948), the integrated circuit (1959) and the

> microprocessor (1971), without which the personal computer would have remained forever a dream.

Perhaps Levy would have better stated that metaphor was "the key to making" engineering possible, as we discovered earlier. Aside from that, this passage reveals Florman's wish to keep computers properly centered in a historic continuum, one that recognizes the efforts of a heritage of engineering, not simply an unprecedented event of "cosmic importance." Elsewhere, Florman tells us that "the phrase 'hands on,' which has an honored place in engineering tradition and used to refer to gasoline engines, electric motors, and concrete testing machines, now means running one's fingers over a keyboard and looking at numbers on a glowing screen" (*CE* 22).

Seems as if we are unexpectedly stepping onto a battleground where forces are trying to divide the already heterogeneous engineering community. Ed Lazaowska, chair of the computer science department at the University of Washington, is quoted in a *New York Times* article on the recruitment of future software engineers, as saying "The pitch I make to high school kids is: 'Where's the intellectual excitement? Why would you choose civil engineering or mechanical engineering? There's only so much you can do with asphalt'" (Harmon D6). It turns out that Florman had already prepared a response to these questions, some time before they were asked. A chapter from *The Civilized Engineer,* entitled "The Fantasy of an Electronic Future," is almost a direct response to this professor's questions, published over ten years ago. In it, Florman describes reading the anniversary issue of *Omni* magazine where various "noted scientists, engineers, and science writers . . . speculate about the future, and the resulting special issue was a striking example of the buoyant overconfidence that irritates me no end" (CE 134). From

Isaac Asimov on how microprocessors would automate society and eliminate repetitive labor, to Ray Bradbury on the similarities between space travel and the births of several religious figures, to René Dubos who foresaw no end to technological innovation,

> these visions made for stimulating reading. But as I sat in my armchair one evening, turning glossy pages of the magazine, I felt as if I was drifting into a world of fantasy. This was the future discerned, all right, but it somehow seemed ethereal. Hopefulness is nice, particularly on an anniversary, but something important was totally absent from these visions, something I couldn't quite put my finger on. (135-36)

The next day Florman is driving along the West Side Highway, when he saw "what was missing from *Omni*'s picture of the future," that "the actual road to the future unfolds before us and anyone with eyes can see that it is full of potholes." Literally, he says. A crumbling technological structure was forcing itself into Florman's consciousness through the wheels of his car, rattling free from his thoughts that which he had been unable to identify before, the source of his discontent with the *Omni* essays. A century's worth of roads, bridges, water pipes, and so forth was coming apart because funds were not being allocated for its maintenance. It would be one thing, he says, if we were to abandon these structures and roads in the same way we abandoned canals after the railways took over. "This sort of thing is not about to happen again, much as we like to talk about sitting at home and communicating electronically." While this may be *Omni*'s version of the future, people, realistically, "want to move about physically" and "the millions of tons of materials that form the basis for our civilization" need to move physically as well. No amount of electrical interconnectedness will achieve that. Simulated reservoirs won't supply us with water. Simulated generators won't power the latest thing in lap-top computers (138).

Florman finds a counterpoint to the *Omni* future, and, perhaps the basis for his prescient response to Lazaowska, in the pages of the journal of the American Public Works Association. Articles there describe techniques for stopping the sinking of Pennsylvania coal towns, the development of new generations of polymer concretes and epoxies for highway repair, purification techniques for contaminated ground water— all of which, while lacking the luster of the electronic era, are high order achievements nonetheless (139). Why choose civil engineering? Because engineering is fundamentally about solving problems. Where's the intellectual excitement? The thrill is in the solving. That is Florman's point.

As for asphalt, Florman says:

> Even lowly potholes are coming in for their share of attention, as well they should considering that each year in the United States approximately two hundred million of them have to be filled. The problem has been studied at the U.S. Army Corps of Engineers Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. One finding is that, in the long run, holes simply filled and compacted by hand cost five times as much as holes that are trimmed, cleaned, dried, lined with a tacking material, then filled and finally compacted by machine. This is not exactly the sort of discovery for which Nobel Prizes are awarded, but it is nevertheless something worth knowing. (139-40)

In closing his chapter, Florman tells of the painting by Pieter Breugel the Elder, *The Tower of Babel*. The top of the tower gleams with new construction, its "new stone walls glow orange against the pale sky," while its "foundations . . . are dark and beginning to crumble" (140).

Before moving on to Kidder, I would like to point out another place—in *The Introspective Engineer*—where Florman takes on cyberspace. Florman is cynical about the idea that computers will make learning fun, especially science learning, which requires an "ability to assess experimental evidence, comprehend mathematical verities, and refute false appeals to intuition" (88-89). Computer-guided tours through cyberspace, contends Florman, might promote "caprice and inspiration" but they may come with a loss of "discipline, concentration, and restraint." Because cyberspace offers a freewheeling tour of knowledge, it demands that no real structure be placed upon your thoughts; likewise, it demands neither organization nor "focus" (89). Florman believes this will weaken the ability of today's children to do engineering and technical work as adults. Remember this notion as we work through *The Soul of a New Machine*. The story's protagonist, a fellow by the name of Tom West who builds computers for a living, will call computers "irrelevant" (180).

Kidder's book differs from the other two we have looked at in that it traces the development of an engineering project from conception to completion. We are taken into the engineering process by way of both the technical issues and the personalities involved. Issues of risk and reward, of practicality and perfection, come into consideration as we watch the computer take shape. More than anything, however, we come to understand the pleasure—the "existential pleasure" even—that the builders of machines get from their work. At a time when computer programmers are scarce, when students are turning away from software engineering because they find it "boring" or passionless, when typical jobs for computer science graduates as "cubicle hackers" or "code machines" turn them into "people who type endless streams of commands to someone else's specifications," we will meet in Kidder's book people who were doing this kind of work twenty years ago and clearly saw it as beautiful (Harmon D6). We will also learn that it takes a certain personality to program computers, and we may come to understand that this personality is typical among engineers.

To understand Kidder's book is to understand somewhat the construction of a computer, at least from the standpoint of what might be called "conceptual engineering." That is, we learn first about the hardware, then about the software, and then about both, as the two come together in what eventually becomes the Data General Eagle computer. The story takes place in the era before IBM's personal computer had arrived, back when the latest technological art was still done in minicomputers. Kidder is surprised to find that the hardware hardens only in its final form, that it remains flexible during a big portion of the design process:

> The machine took its first material form in paper—in a fat volume of pages filled up with line after line of 0's and 1's, and in bound books large as atlases that contained the intricate geometrical descriptions of the circuits, neatly drawn by their draftsman. You could think of this small library of microcode and schematics as the engineers' collected but not wholly refined thoughts on a variety of subjects. The language was esoteric, but many of the subjects were as familiar as multiplication.
>
> I had imagined that computer engineering resembled the household electrician's work, but it seemed the bulk of it lay in making long skeins of logical connections, and it had little to do, at least at this stage, with electricity. (121)

I suppose we too could somehow divide our search for the beauty of the computer by looking first at hardware and next at software, taking each as an entity unto itself. Approaching the computer in this sequence, we would be examining it as we did the jetties and the motorcycle, in levels of increasing abstraction. This makes sense, especially when one considers that the electrical schematics are symbolic of the computer circuits that will ultimately exist in a physical form, whereas the microcode will know no physical realization, other than as electrical energy down in the guts of the computer. Kidder provides us with a couple of nice passages about this abstractness. Printed circuit boards, he says,

> are colorful and most finished ones please the eye. A computer's boards seem to show order triumphing in complexity. They look as if they make sense, but not in the way the moving parts of an engine make sense. The form on the surface of a board does not imply its function. (31)

On microcode, Kidder says,

> Most new microcoders, on their first job, have the odd feeling that what they're doing can't possibly be real. "I didn't fully believe, until I saw it work, that microcode wasn't just a lie," said Alsing's main submanager, Chuck Holland, remembering the first code that he wrote. At the level of the microcode, physical and abstract meet. The microcode controls the actual circuits. (97)

On the other hand, it might be better simply to follow Kidder's organization and discuss the aesthetic of the computer as it is revealed in the sequence of the text. He has an organization that works, obviously.

Early in the book Kidder discusses the history of the computer industry, the history of the IBM corporation, of the Digital Equipment Corporation, and the beginnings of Data General as the corporate upstart. In the late 1960s, Kidder says, IBM was the prevailing manufacturer of mainframe computers of the kind employed by large accounting firms, for instance. Another market existed for smaller machines, known as "minicomputers," that served technical types and, especially, original equipment manufacturers—OEMs—who could buy the machines, build software for them and sell them as ready-to-run machines to users in specific industries. It was into this other market that Digital Equipment Corporation and a great many others put their efforts. Digital's star was the PDP-8. It was the computer that basically launched the minicomputer idea. In 1968, one of the engineers that designed the PDP-8 left Digital along with two other co-employees to start Data General. Their machine, the NOVA, was very much a success, due in part to its design, which Kidder describes here:

> The company's first machine, the NOVA, had a simple elegance about it that computer engineers I've talked to consider admirable, for its time. It had features that DEC's comparable offering didn't share, and it incorporated the latest,

> though not fully proven, advances in chips. Data General could build the NOVA very cheaply. Such an important advantage can depend, in computers, on small things. In the case of the NOVA, the especially large size of the printed circuit boards—the plates on which the chips are laid down—made a crucial difference. For several reasons, large boards tend to reduce the amount of hardware in a computer. Data General used boards much larger than the ones that DEC was using. Speaking of this difference and other less important ones, one engineer remarked, "The NOVA was a triumph of packaging." (17-18)

Data General's success with the NOVA set the stage for other computer developments. After NOVA came the Eclipse. This machine, another winner for Data General, was essentially a "refinement of the NOVA" (45). Both machines were designed around a 16-bit architecture, unlike the IBM mainframe machines of the day which used 32-bit architecture. The difference between a 16-bit machine and a 32-bit machine, Kidder says, involves things like processing speed and programming ease, and—even more importantly for minicomputers—the number of unique addresses that can be assigned within a computer's memory. That is because these 16- and 32-bit "words," as they're called, are used not only as the means for chunking information, but also as addresses by which the computer keeps track of the information. Like a telephone number, to borrow Kidder's analogy, the longer the word, the higher the number of addresses that can be assigned:

> A 16-bit machine can directly generate symbolic addresses only 16 bits long, which means that it can hand out to storage compartments only about 65,000 unique addresses. A true 32-bit machine, however, can directly address some 4.3 *billion* storage compartments. (35)

Digital Equipment, Data General's principal competitor, had just introduced a 32-bit machine which they had dubbed the "VAX 11/780." Data General would need to respond in kind, because, although many users were still happy with the capabilities of their 16-bit machines, others weren't, and "a general feeling held that 32-bithood would become a de facto standard in the industry. You had to produce a 32-bit machine" (35).

Actually, Data General had been working on the design of their 32-bit machine already when Digital introduced the VAX, so it wasn't as if they'd been clobbered. Data General's 32-bit machine was called FHP, an acronym for the Fountainhead project, which had been taken from the name of the apartment building where Data General had rented space so that members of the new project's development team could work in secret. The FHP project eventually moved out of Massachusetts, the birth state of Data General, to the company's new division in North Carolina. The engineers who stayed in Massachusetts would continue to build NOVAs and Eclipses, something that for hot shot computer engineers was akin to bringing home a highly trained police dog and chaining it to a peg in the backyard, where it could serve on pet duty.

One hindrance to introducing new computers was the hesitancy of computer users to relinquish software that had been tested and proven and debugged. Much of the software of that time was custom written, one-of-a-kind code. Those users who had developed programs at great expense and headache would refrain from buying a new machine that could not run old programs. Why buy new computers, though they might offer faster processing speed, if it meant trashing perfectly acceptable programs that were already in place? And those users who were willing to develop new programs had no real incentive for staying loyal to one computer manufacturer. If they had to buy new software to work with a new computer, why limit themselves to the computer brand they were then using? There were really two things that would sell more computers: increased memory size by way of 32-bit architecture and "software compatibility." If a machine could operate with a larger memory, yet still run programs designed for 16-bit architectures, then the designers of such a machine would have a good chance of it succeeding in the market. A suggestion came from the FHP team that the engineers remaining in Massachusetts put together a "small machine" that offered the two features, 32-bit architecture with 16-bit software compatibility (37).

> Some of those who stayed behind felt determined to build something elegant. They designed a computer equipped with something called a mode bit. They planned to build, in essence, two different machines in one box. One would be a regular old 16-bit Eclipse, but flip the switch, so to speak, and the machine would turn into its alter ego, into a hot rod—a fast, good-looking 32-bit computer. West [the Massachusetts manager] felt that the designers were out to "kill North Carolina," and there wasn't much question but that he was right, at least in some cases. Those who worked on the design called this new machine EGO. The individual initials respectively stood one step back in the alphabet from the initials FHP, just as in the movie *2001* the name of the computer that goes berserk—HAL—plays against the initials IBM. The name, EGO, also meant what it said. (37-38)

A period of sweat and toil ensued in both camps. Two months later a specification had been written for EGO, but it was clear that the resources of Data General would allow them to make only one new machine; Data General's money would be backing the North Carolina group. EGO was dead. Once again, the engineers remaining in Massachusetts were on pet duty. Talk there eventually turned to the idea of charging up the 16-bit Eclipses so that they might run "faster by a factor of two, or maybe even four, than any the world had ever seen" (40). However, enthusiasm stayed out sick.

So many engineers had poured themselves into the EGO project that their boss, Tom West, was moved to try to sell the project again to his boss, Ed de Castro. Again, West was told not to build EGO, but was instead asked to "do something to extend the addressing capability of Eclipses" (40). At the same time West was issued one more caveat: no mode bit. Basically, West was being asked to build a 32-bit Eclipse.

In engineering design, starting from a blank sheet is less common than one might expect. Eads may have had one, and for that matter, Tesla may have had one too. Much of the time, though, engineering designs evolve from existing designs, borrowing good ideas from lessons learned, often repeating mistakes as well. Refinement is usually a key objective. Every so often a technological breakthrough or discovery will come along and change the accepted design practice. A fervor of redesign usually follows. One example of such a breakthrough was the advent of the programmable logic controllers, or PLCs, in the machine controls industry. These little computer-based boxes offered a simpler and more economical way to control the sequence of operations of a given machine's process, and replaced the practice of controlling a machine with wire and relay switches in a kind of "hard" logic. Although the PLCs did nothing at the elemental level of logic design—a logical circuit functioned the same whether it was expressed using wire and relays or programmed into the silicon memory of a logic controller—they made building these logical circuits many times easier, and troubleshooting them easier as well. With the cost of a single line of relay logic, as the old stuff was called, reduced so drastically, machine controls could become very elaborate, and self regulating. The real change came from the fact that now each machine on a factory floor had a brain, albeit an extremely limited one, that could communicate with every other machine. An entire factory conceivably could be operated from a central control by far fewer people than had been necessary before.

Of course not all technological breakthroughs succeed, so there is a tendency to let new technologies prove themselves out before a manufacturer of assembly machines, for example, will embrace them. New technology implies training and often a steep learning curve, not to mention a commitment to your customers that you will support the new technology for many years after a machine enters the workplace. And sometimes two competing technologies need time to sort out a clear winner. The video-cassette recorder wars which pitted Beta format against VHS format is one example of two technologies fighting for market dominance. Florman cites another example in the story of fluidics.

> The concept of fluidics was appealing—using liquids or gases to perform functions, such as switching or amplification, that are ordinarily performed by electronic devices . . . . By building networks of tubes, or channels in stacked laminates, with an assortment of intersections and chambers, fluidics engineers created ingenious control systems, which, for a while, appeared likely to prove superior to their electronic counterparts.
>
> Manufacturers set to work etching delicate patterns into glass, metal, and ceramic blocks, and producing plastics networks by injection molding. But they were doomed to frustration. No matter how they struggled to miniaturize their product, they could not keep pace with electronics engineers, who were moving into a microscopic realm. Transistors became incredibly tiny and even more incredibly inexpensive. Also, alas for supporters of the new technology, electricity moves at almost a million times the speed of air jets. Unable to compete in size, price, or speed of operation, fluidics became virtually obsolete almost before its boom could get underway—not quickly enough, however, to save a lot of people from losing a lot of money. (*BT* 16-17)

The difficulty in any engineering endeavor is predicting where the next need will be, or, harder still, where the next boom will be. Those investors who banked on fluidics lost. Florman provides a list of similar examples of loss: Corfram, the Wankel engine, holography, titanium—all demonstrating the fickleness of the market and how it often does not respond to the miracles of engineering. I suppose Data General was in a similar circumstance. Their competitor was out in front with a more powerful machine. They had a new machine under development in North Carolina. They had a bunch of engineers in Massachusetts who wanted "to produce something" (Kidder 69). When the proposal for EGO sank, many of the engineers involved were disheartened, for this would have given them a chance to work from a blank sheet, at least when it came time to build the 32-bit mode of the two-mode computer. When, instead, they were told to make a 32-bit Eclipse, the blank sheet went away. They would be back refining what had been done before: evolution, not revolution. The engineers thought that the machine they were now being asked to build

> would be just a refinement of the Eclipse, which was itself a refinement of the NOVA. "A wart on a wart on a wart," one engineer said. "A bag on the side of the Eclipse." Some even said that it would be a "kludge," and this was the unkindest

> cut. *Kludge* is perhaps the most disdainful term in the computer engineer's vocabulary: it conjures up visions of a machine with wire hanging out of it, of things fastened together with adhesive tape. (45)

What had started as an "elegant" machine—the 32-bit EGO with a mode bit—had now taken on the image of a very inelegant "bag" stuck on the side of an existing machine. The engineer who first put forth this image, a talented machine architect by the name of Steve Wallach, had felt "robbed and insulted" when the company had moved the FHP project to North Carolina. He would be among the first engineers that Tom West would "sign up" to work on the "kludge" (74). West's conversations with him show the depth of this engineer's passion:

> West called Wallach to his office in the spring of 1978 and asked him to draw up the architecture for a 32-bit Eclipse.
>
> Steve Wallach glared at West. Wallach got to his feet, and, coining a phrase, said: "F—— that! I'm not putting a bag on the side of the Eclipse." Then he stomped out of West's office. (68)

Clearly West would be unable to convince Wallach to do this design on technical merit. Wallach had fought hard to keep the EGO going when the company had committed to building FHP, and he was convinced that the reason EGO died was that it "was too good, too much of a threat to steal the show from North Carolina" (74). So dejected was Wallach from this battle that he had decided to quit working for Data General. But West presented him with the gauntlet: "Haven't you realized yet that the way to prove someone wrong is to build the right thing?" (75). Eventually, coming to sense that "conceiving architectures was his job," Wallach decided he would stay if he could get some kind of assurance that this machine, unlike so many that had come before it, would not be canceled. He went to see Ed de Castro, Data General's president:

> "Can I be straight with you?" asks Wallach.
> De Castro nods.
> "Okay," says Wallach. "What the f—— do you want?"
> "I want a thirty-two-bit Eclipse," says de Castro.

> "Are you sure? If we do this, you won't cancel it on us? You'll leave us alone?"
>
> "That's what I want, a thirty-two-bit Eclipse and no mode bit."
>
> Wallach returned to West's office, and now, at long last and sniffing, he said, "Okay, Tom, one more time."
>
> "The document's yours," West replied. "You gotta do it fast." (75-76)

What may not have been understood by Wallach then, but, for West had become readily apparent after he spent some time with an unnamed person in Data General's marketing department, was how strong an entry this new machine could be. Digital Equipment's VAX, while being a 32-bit machine, was only "'culturally compatible' with the line of machines that preceded it." The new Data General machine, to be built in an almost clandestine operation as "insurance" (47) against North Carolina's FHP coming up short, would be called "Eagle" (sounding like "Ego" when spoken) and would be "*fully* compatible with Eclipses" (44). West began promoting the machine inside his department not as a refinement of the Eclipse, but as a "wholly new and fast machine that would happen to be compatible with Eclipses" (45). Outside of the department, however, he would promote it as merely "a fast Eclipse-like machine" (47). Whatever the marketing department at Data General may have known about a 32-bit machine with full 16-bit compatibility being elegant in the marketplace, Data General engineers assigned to the Eagle project would have to come to by design. Until then, the engineers would remain skeptical.

Wallach would be the first to cross over, to see the new machine no longer as a "wart on a wart on a wart, but as a clean design with a wart on it. The wart was the Eclipse instruction set, virtually every part of which Eagle would have to contain, for the sake of compatibility" (82). How he came to see it in this was partly due to what Kidder terms a "golden moment" (80).

Wallach had been working for a time on the architecture of the new Eagle, defining "not how the machine would be built, but what it [would] do" (67). Among the tasks before Wallach was how to protect the computer from users entering certain portions for which their entry was not authorized. He decided upon a ring system of security, which the VAX designers had also used. The VAX used a system where each "compartment in memory had an address, and each compartment also had a separate ring number" (79). The ring number associated with each compartment would correspond to a specific level of authorization. The levels of authorization were represented by three binary bits, whose combination allowed for eight different possibilities, hence allowing eight levels of security. Like the ring number, the segment number for each memory compartment was defined by three binary bits, permitting up to eight "area codes" (80). The remaining 29 bits of the 32-bit address would make up the rest of the memory compartment's "telephone number." Kidder continues:

> The segment number—the area code—would be the same as the ring number, which defined the level of security to which the compartment would be assigned. Three bits can be combined in eight different ways. So there would be eight rings (eight levels of security) and eight segments (eight area codes) in the memory system. The area codes would themselves indicate which ring was forbidden to whom.
>
> Although they are generally shy about claiming to have had one, engineers often speak of "the golden moment" in order to describe the feeling—it comes rarely enough—when the scales fall from a designer's eyes and a problem's right solution is suddenly there. The chief virtue of Wallach's scheme was its simplicity. It would be relatively cheap and easy to implement in hardware and software, and it should work efficiently and reliably. When Alsing saw Wallach's brief description of the plan, he said to Wallach, "That's nice." Later, out of Wallach's earshot, he said more. "Rings have been around. They're old hat. What makes Wallach a good Data General engineer is that he came up with a really elegant subset of those ideas—simple, sweet, cheap, efficient, clean . . . ."
>
> As for Wallach, after he had drawn the diagram, he stared at it, wondering for a moment, "Where did that come from?"
>
> He kept eyeing it. "That looks pretty cool."
>
> For the next couple of weeks Wallach played with the idea, until he was sure it would work. Then he pulled his computer terminal in front of him and

> wrote up a memo, which told how others had handled memory management and protection in the past and which described his own general scheme. Near the end of the memo, his sarcasm rose. He described the plan as a kludge, but a better one than DEC had put into VAX. He kicked his walls a few times. The idea of placing that neat, clean structure on top of the outdated structure of the Eclipse repelled him. It was as if he had invented a particularly nice kind of arch for the doorway of a supermarket. (80-81)

Wallach afterwards envisioned a number of scenarios in which he was up against the board of computer-memory inquisitors, having to defend his choice of memory schemes by denouncing the shackles that Data General's management had placed upon him. Fellow artists, the inquisitors would wonder why he had used such an unsophisticated set of instructions. The answer, of course, was by design: the Eagle had to be able to run every program that the Eclipse could run. He had no blank sheet to work with, but a rather full one at that, yet he had been able to devise a new way to see a problem just as Eads and Tesla had done. Wallach eventually came to find the new computer's architecture more and more appealing, finding territory within it where some pretty fancy stuff would be placed.

With the architecture of the new machine complete, it became the task of the microcoders to start writing the instructional code that would enable Eagle to transcribe instructions written in higher level programs into the electrical signals at the circuit level. Carl Alsing was appointed by West to head up the team of microcoders. Alsing is described by Kidder as the kind of engineer who, at first glance, seems to be "shut off in a little corner and doesn't give a damn about anything except his own little thing" (91). Indeed, Alsing demonstrates many of the traits that are often ascribed to engineers: little interest in sports, bookish, uncomfortable with their own physical presence . . .

> Alsing is tall, over six feet, but he doesn't seem to realize it and he doesn't look that big. He is neither fat nor thin. He keeps his hair cut fairly short. Often his dress looks sloppy—not deliberately or extremely so, but slightly careless. He speaks softly, as a rule, and the pitch of his voice, though not at all squeaky, is

> high. About his hands, the way he folds them in his lap or puts them together under his chin, there is something delicate. One acquaintance of his said, "He looks uncoordinated." In fact, Alsing does not play many physical games, though on a vacation in the Caribbean he took up scuba diving. Ham radio is an old hobby of his. I thought that I could see in him the lonely childhood behind him—he would have been the last boy picked in every schoolyard game, the one who threw a ball like a girl. But Alsing is gregarious. He set out some years back to master social gracefulness, and it shows. He will sit down in a strange living room, fold his hands in his lap, and listen. You can forget that he is there, until gradually, so delicately you hardly notice, he enters the conversation. After several such occasions, people who had just met Alsing said to me, "He's really smart and interesting, isn't he?" (92)

As did many of the engineers Kidder describes in his book, Alsing suffered a rather lonely childhood. He was something of a social outcast, and at the "bottom" of the "pecking order" (92). He found solace, though, by taking things apart and putting them back together. Alsing showed every intention of not amounting to much as he went through high school. The same held true in college, save for a psychology course where he did well. It was a course in digital circuits, and especially the section pertaining to Boolean algebra, which eventually woke him from his slumber.

> Alsing's world was never the same after that. Fathoming this algebra, Alsing felt as some children do when all at once they know how to read. Boolean algebra was something that made perfect sense, and thus it was a rare commodity for him. He called it beautiful. (93)

As one company executive would comment, Alsing had "written just about every line of microcode that [had] come out of Data General" up until then, but the new machine would require more code by itself than had all the other earlier Data General machines put together (103). At the time of Eagle's inception, Alsing was in his middle thirties, and losing some of the intensity for the work that programming required. Maybe his hands-off management style fit perfectly with his job of overseeing the microcoders. It would be different from the work habits that he practiced when he had coded earlier Data General machines such as the Eclipse. Back then, Kidder says, Alsing would procrastinate for months producing little to nothing. Then, sensing trouble from management about to descend upon him, he would pack his stuff off to the local library. There, with his blank yellow tablet in front of him, Alsing would more or less unstop a bottle full of thoughts that he had been filling up for months, and line after line of code would pour onto the pages. Alsing describes the process:

> Writing microcode is like nothing else in my life. For days there's nothing coming out. The empty yellow pad sits there in front of me, reminding me of my inadequacy. Finally, it starts to come. I feel good. That feeds it, and finally I get into a mental state where I'm a microcode-writing machine . . . .
>
> You have to understand the problem thoroughly and you have to have thought of all the myriad ways in which you can put your microverbs together . . . . You take all the pieces, put them together, pull them apart, put them together. After a while, you're like a kid on a jungle gym. There are all these constructs in your mind and you can swing from one to the other with ease. (102)

That is how Alsing managed to write the microcode for the Eclipse. In the end the code was not elegant—Kidder calls it a "kludge"—but a collection of serpentine trails, "tricks and subtleties." Alsing's artistry with the Eclipse, as Wallach's had been with the Eagle, was hampered by the reality of "a severely limited storage space" (102). Still, Alsing had worked magic within the confines of his coding space. Now, with the Eagle project underway, Alsing came to realize that this machine's microcode too would be something short of elegant. After all, the new Eagle would be running many of the programs that had been written to run on the old Eclipses. Some of the tricks he had put into the Eclipse's microcode would be carried over to the Eagle's.

> *Kludge* made Alsing imagine a wheel built out of bricks, with wooden wedges in between them; such a thing might work, but no sane engineer would be proud to have designed it. Alsing tended to agree with those who maintained that Eagle must, by definition, be something of a kludge. (103)

The artistic impulse seems as if it must be part of the make up of a creative engineer. The two engineers that we have met here worked hard to establish elegance in their designs. Of course, the expression of elegance in their work was hindered by the constraints placed upon them by the realities of the market. Neither engineer had the opportunity to create starting with a blank sheet of paper. Instead, they had to adapt to existing designs, and find elegant ways to work within what might have been inelegant terrain. One of the things we will discover as we learn more about Tom West is just how strong this urge to be creative is; engineers routinely need to be prodded along to the next assignment before they turn what should be good enough into a masterpiece. There is a "tendency for all bright young engineers to redesign and redesign in search of perfect unattainable solutions" (148). A masterpiece takes too much time. Florman has a few comments to make about perfectionism in engineers, and exploring some of his ideas about the "civilized engineer" may give us insight into the actions of Kidder's hero, Tom West. But before that, I'd like to look at how the artistic impulse surfaced in another form apart from engineering.

The construction of the Eagle computer was undertaken as a kind of insurance policy to protect Data General from a failure by the group in North Carolina. That at least is how West had sold the project to his managers. This meant that many of the engineers that might have worked on Eagle in Massachusetts had moved to North Carolina and were working on FHP. It also meant that Data General had to recruit workers for the Eagle project, but on a restricted budget. So, West and Alsing decided to follow the example of Seymour Cray. Cray was the manufacturer of the Cray computer, and he hired his engineers right out of school because "they do not know what's supposed to be impossible" (59). Adopting this strategy, West and Alsing prepared to do some creative interviewing.

Alsing did not hire engineers that were all alike. He "had shown eclectic tastes" in the recruits he picked for the Eagle team, Kidder says (156). Some were rock musicians, others were sculptors. One in particular, Chuck Holland, was hired by Alsing specifically because of the sculpture he was working on at the time of the interview.

> "I'm working on this thing," Holland had said, when in his interview, Alsing had asked him what he did for fun.
>
> "Tell me about it," Alsing had said. So Holland had, and by the time he had finished, Alsing had felt sure that Holland could write microcode. "It was my clue that he could make something intricate work."
>
> From a distance Holland's sculpture looked like a rectangular cage, and closer up, a gallery of spiders' webs. It stood roughly five feet high. Thin steel rods attached to each other at odd angles made up the four outer walls of the cage. The top made a sort of funnel, somewhat like a coinbox on a bus—four sloping planes that narrowed down around a little hole. Rather shyly, Holland dropped a handful of silvery steel balls into this funnel, and the sculpture went to work . . . .
>
> [Holland says,] "At first I just wanted to make it work. It was an engineering feat for me. Then I decided I wanted to hide the track, but then I decided the track's kind of neat so I let some of it show. I wanted it to have some meaning. I have my own ideas on form. Planes and so on." He ran his hand across one section of the outer walls, as if stroking an animal's fur. "These wires cut this plane, and I just think that's really neat." It had taken Holland months to build this thing, taking it apart, putting it back together, taking it apart again. (157-58)

Alsing's decision to hire Holland and train him turned out to be one of his "crucial contributions to the project" (156). Actually, Holland had been hired a few years before the Eagle project, but he became the person Alsing relied on to organize the microcode that Alsing's programmers would write. Something in the intricacy of his sculpture tipped Alsing off that this man would be adept at organizing an undertaking as complex as coding a computer.

Another engineer, Wallach (whom we met earlier), expressed his artistic impulses by quoting passages from the likes of "Victor Hugo, Nietzsche, Shakespeare, T. S. Eliot, Santayana and FDR" in a two-hundred page book he was keeping to document the Eagle's specifications. Wallach

> had not read widely the classics. So the epigraphs for his book didn't come without effort . . . . Some were playful and some downright witty, if you

understood the context. At the top of the chapter about the instruction set, for instance, he placed this quote from *Macbeth*:

> *We still have judgment here; that we but teach*
> *Bloody Instructions* [Wallach's cap.], *which, being taught,*
> *return*
> *To plague the inventor.*

> Wallach spent about twenty hours in the Framingham Public Library, with his nose in *Bartlett's Familiar Quotations* and dipping into some of the actual works, just to add these flourishes to his spec. They added something. They revealed the class of feelings that Wallach brought to his job. If he was a Hessian, he was a passionate one, and with the quotations he signed his name to his piece of the new computer. (84)

A third engineer in Kidder's story is revealed as having a penchant for writing. Ed Rasala was something of an anomaly in the group of engineers that worked on the Eagle project. The son of Polish working-class parents, he had grown up in New York, playing softball, earning a high-school equivalency diploma, always following in the shadows of his mathematician brother who received all the teachers' praise. Rasala describes himself as not living up to his potential. He went to Rensselaer Polytechnic Institute where he studied electrical engineering. His first job at Raytheon was a good place to meet other softball players, but he was never gripped by an urgent need to test his mettle on work-related projects, nor did he recall "the feeling, which others in the Eclipse group remembered, of having his true calling suddenly revealed to him the moment he touched a computer" (141). It was not until seven or so years into his stay at Raytheon that Rasala was given a project that challenged him. He rose to the occasion and emerged victorious. Along the way, he found a liking for project responsibility. Yet, his reputation for mediocre output at the company meant he would have to look elsewhere to find other challenging assignments. That is when he went to work for Data General.

Kidder writes, "Most people, at one time or another in their careers as adults, reenact the molting of their adolescences" (282). Rasala liked to think of his move to

Data General as the point where he emerged professionally into adulthood from a childhood spent at Raytheon. Actually when Rasala was first approached by West to manage the hardware development for the Eagle project, he declined, citing a tiredness that he felt after just finishing another long project on the Eclipse line. West pursued Rasala, however, and without ever formally agreeing to do so, Rasala eventually found himself deep into the managing of the Eagle's development. It was the kind of responsibility that West knew Rasala was ready for, even though Rasala himself hadn't known it at the time. To cope with the uncertainty and pressure of managing Eagle's circuit builders, Rasala started keeping a journal, one with a notably artistic twist. Kidder continues:

> An engineer was supposed to be eager to advance in his company's hierarchy, and Rasala was, but he had other dreams. Some years before, he had taken a trip to Jackson Hole, Wyoming, and ever since, he had wanted to go back there and do something simple: he thought he'd like to open a grocery store in Jackson Hole someday. To Rasala, many of the young [hardware engineers] seemed hip and cultivated in ways that were foreign to all his previous experience of engineers. But he did not for that (or any other) reason disapprove of them. And he didn't seem to envy them or want to change his ways and be just like them. He talked about them with plain curiosity, as if he were a traveler in their country.
>
> One evening, over beers, Rasala complained about some insipid movie recently shown on TV. He compared this stinker to *The Prime of Miss Jean Brodie*, an example of a film he'd liked. Actually, he had admired the protagonist most of all. "I don't know why," he said. "She's romantic, foolish, unrealistic—everything an engineer's not supposed to be. But I like her . . . ."
>
> When the hardware team started to design Eagle, Rasala opened a sort of diary. It reads like the journal of a frontiersman's travails, except that instead of wolves, hostile Indians and busted wagon wheels, the reader encounters the indecisiveness of logic designers, an affliction that causes a designer to "spin" from one possible approach to another; the regular breakdown of the computer they were using to work on their computer; and the tendency for all bright young engineers to redesign and redesign in search of perfect unattainable solutions. In the diary, one delay follows another. Schedules always slip. The last entry, recorded several months before they stopped designing, reads, "Overall, things look lousy." (147-48)

Somehow after reading *The Civilized Engineer* we are not surprised to find several of the characters in Kidder's book having an interest in art and literature. Florman cites many examples of engineers who have had artistic interests or accomplishments outside of their technical roles. "Steven Jobs, fabled co-founder of Apple Computer, Inc. recalls that between his sophomore and junior years at Reed College in Oregon he discovered Shakespeare, Dylan Thomas, 'and all that classic stuff'" (193). Allen Kay, who was high in the upper echelons at Apple Computer, was a musician first, turning the direction of his graduate study to computers only after first earning a bachelor of arts degree. These two artistically-inclined engineers from our time, Florman says, join a long list of engineers from the past who too had artistic temperaments. "Samuel Morse was a well known painter and president of the National Academy of Design long before he became interested in telegraphy." Robert Fulton, the inventor of the steamboat, "studied painting in London under Benjamin West." The Roeblings, the father and son team that designed and built the Brooklyn Bridge, "were both accomplished musicians" (187-88). Florman might go so far as to say that the reason many of the engineers in Kidder's book were successful is that they had artistic impulses. Tom West certainly had art in his past.

Tom West, Kidder says, lived a childhood similar to that of many of the engineers portrayed in the book. Like Carl Alsing, West would spend hours building and taking apart sailboats or automobile engines or trailers. Success in these activities came easily to West, more so perhaps than did excellence in the academic disciplines. West was intelligent, however. One of his college classmates would describe him as "smart—off the charts," but he was one of the first students at Amherst College to enter the "underachiever" program there, which, according to Kidder, had been set up to help those students whose work did not measure up to their brains. As such, West was suspended from the college for a year with the intent that the time off would give him a chance to mature. During that year, West played guitar in coffeehouses around Cambridge, Massachusetts, re-creating the feeling he had had as a boy when he had played the trombone "in the town band with his father." He returned to Amherst College a year later—in "the very early sixties"—and found that this time spent as a musician had prepared him well for the shifts in the social structure that were then taking place.

> West would say, "People were leaving Harvard and becoming masons." As for himself, he decided to become an engineer. Some of his friends were astonished. The very word, *engineer*, dulled the spirit. It was something your father might be interested in.
>
> "I think I wanted to see how complicated things happen," West said years later. "There's some notion of control, it seems to me, that you can derive in a world full of confusion if you at least understand how things get put together. Even if you can't understand every little part, how infernal machines get put together." (175-76)

After college, a hoped-for job in the space program did not materialize for West, but one with the Smithsonian Institution did. This work took him to far away places, where he monitored satellite tracking installations that had been placed all over the world. He saw South America, Africa and Asia. "He went to sea," Kidder says, spending seven years "as a far-wandering engineer" (176).

Family matters with his wife and children eventually brought West home. Some of the musician friends whom he had met during his year off from Amherst College had become well known on the folk-music circuit. West began thinking about resuming his own music career. Of course, he would still need to find day work to support his family, so he set about to find "some easy, mindless job," that could also keep him out of the Vietnam War (176). It was about this time that "West decided to become a computer engineer." Six weeks of cramming at the local library on the fundamentals of "logic design" was enough to get him a position at nearby RCA.

> It did not work out as he planned. "I thought I'd get a really dumb job. I found out dumb jobs don't work. You come home too tired to do anything," he said. He remembered a seemingly endless succession of meetings out of which only the dullest, most cautious decisions could emerge. He remembered watching himself

> play with his thumbs beneath the edges of the conference tables for hours and hours. Near the end of his time at RCA he got to work on projects that interested him. He saw a few patents registered in his name. He became what he pretended to be, a real computer engineer; but by then RCA had lost a fortune trying to compete with IBM and was getting out of computers. The time to change jobs was upon West again. (177)

Somehow, it seems, designing computers began to instill in West the same sense of creativity and accomplishment that he had gotten from playing music. After leaving RCA, West went to work at Data General, where, almost immediately, he was put to work designing the first Eclipse. During this project West would find himself worried sick over its outcome, until the machines were finished and spewing off the end of the assembly line. Watching them, West underwent an "almost . . . chemical change." After that, says Kidder, what West "wanted most of all to do then was to do it all over again someday, only better" (178). Describing his job building computers, West would say, "There's a big high in here somewhere for me that I don't fully understand" (179).

Reading about West, I couldn't help but see similarities between his early years and Florman's. After college both men traveled: West, as a representative of the Smithsonian Institution; and Florman, as a Civil Engineer Corpsman for the 29th Construction Battalion. West's travel, combined with the fact that while he was growing up his family moved often on account of his father's work as a high-level AT&T executive, gave him an air that allowed him easily to find "his way among strangers" (53). Florman experienced a kind of cultural awakening as well. While serving on the Pacific atoll of Truk, he ran into a chaplain who challenged him and his fellow engineers to reach beyond their favorite topics—"work, the current baseball season, and girls"—thus sparking for Florman "an epiphany of sorts" that made him question why engineers led lives that were "so far removed" from the world of politics, religion, and morality (*CE* 10). Though we don't know that West has done the kind of reading that Florman has, he clearly has given his life's philosophy much thought. West held deep seated beliefs on technology, on risk, and on engineering, which in many ways parallel Florman's ideas of the civilized engineer. And West, even in the face of what might be Kidder's artistic license, clearly could pass for the larger-than-life engineer that Florman has in mind. West, for Florman, is a hero.

The idea of a civilized engineer is a theme that crops up repeatedly in the four Florman books. Florman writes in the preface to *The Introspective Engineer*,

> This is the fourth book in a loosely connected series that began in 1976 with *The Existential Pleasures of Engineering*. In that work my main objective was to celebrate the intellectual and spiritual wonders of the technological impulse. In *Blaming Technology* I sought to defend engineers from the unwarranted allegations of their critics. In *The Civilized Engineer* I asked my fellow professionals, in effect, Why can't we be better than we are? (xii)

It has been Florman's purpose all along to elevate the stature of engineering. As time goes on, though, Florman begins to realize that a higher professional status for engineering isn't necessarily what all practicing engineers desire. Many of the "rank and file" are content with "a modest level of technical challenge combined with the opportunity for periodic promotion and their share of organizational recognition," Florman explains, quoting from a study of Rochester-area engineers (124). After seven years of traveling for the Smithsonian Institute, perhaps West sought this kind of work himself, having abandoned his college-years' yearning for engineering work that had a high level of "complexity" (176). What happened to West in those years between college and the end of his Smithsonian stint so that he grew discontented with engineering, willing to abandon it for the pursuit of a musical career? Florman says, "The history of engineering reveals many important contributions . . . made by underlings and independents, even by malcontents, and especially by mavericks" (*IE* 125). Could it have been West's dissatisfaction with engineering that eventually led him to lead a major project at the technological forefront? I like to think of West as being just such a maverick.

In the opening scene of Kidder's book, West is introduced to us as the helmsman of a sailboat underway in a North Atlantic storm. Aboard are several other men. As these men succumb to varying degrees of storm sickness, "that half-autistic state that the monotony of storms at sea occasionally induces," West draws energy from the storm's fury. Kidder writes, "High spirits had apparently possessed him from the moment they set sail, and the longer they were out in the storm, the heavier the weather got, the livelier he grew" (4). While the others are nursing upset bellies, West is drinking a beer. Later in the book we learn a little of the philosophy that compels West's behavior.

> In relatively serene times, some years before Eagle, West and his wife had made friends with an electrician who lived in their town. The man's name was Bernie. He owned a small airplane. Since West's farmhouse and barns lay under one line of approach to the little local airport, Bernie often flew over. When he did, he would waggle his wings, he might do a quick roll; sometimes he'd climb halfway out of his window and wave down at the Wests. "Bernie likes to fly upside down," West remarked, and he and his wife shook their heads and laughed.
>
> Alsing often heard West talk about flying upside down. It seemed to mean taking large risks, and the ways in which West used the phrase left Alsing in no doubt that flying upside down was supposed to be a desirable activity—the very stuff of a vigorous life. (117)

Even later, West says about building Eagle:

> Among those who chucked the established ways, including me, there's something awfully compelling about this. Some notion of insecurity and challenge, of where the edges are, of finding out what you can't do, all within a perfectly justifiable scenario. It's for the kind of guy who likes to climb up mountains. (181)

West's proclivity for taking risks shows up a number of times in the book. The decision to hire engineers fresh out of school was a risky one. How could Data General be sure that these engineers, without any professional experience, would be capable of starting and completing a project as large, as complex, and, ultimately, as important to the success of the company as the Eagle machine was? "Shall we hire kids, Alsing?" was how West framed the debate (59).

Another risky decision was the strategy to design the new computer around the electronic devices known as PALs that were just then coming into the market. Kidder writes, "The conventional wisdom holds that in making a new computer, you never plan on using any sort of brand-new chip unless at least two companies are making it." This was because chip manufacturing was susceptible to sudden, unexpected shutdowns brought about by events such as clean-room contamination. At the time West made the decision to go with PALs, only one manufacturer was producing them. Banking that they were "the coming thing," West elected to use PALs (118). It was a decision that paid off, eventually, as they would become the "chip of the future" (268). Before they would, though, the one manufacturer of PALs would come close to bankruptcy, making imminent the possibility of losing "the whole thing right there" (231). In fact, Kidder makes it clear just how much of the enterprise of building the Eagle had been fraught with risk:

> Although he had rarely confessed it to anyone in the company, West had taken a large gamble. "You have to believe in yourself enough to make some pretty outrageous statements," he had said, referring to his largely successful efforts at selling the virtues of Eagle. Secretive as a mother cat about the location of her kittens, West had masked most of his activities, including his worrying. (278)

Much in the same manner that the Army Corps of Engineers worried over the ability of their Mississippi River structures to contain the waterway, West worried about how certain decisions would affect the outcome of the Eagle project. In some ways we are reminded of the Corps' arrogance, as McPhee described it, when we examine West's approach to risk-taking. Perhaps prudence is the wiser decision when lives and property are at stake, and maybe in such a situation a man like West would act less boldly, be less willing to gamble, than he was when it was merely economics at stake. We remember Fred Bayley, the engineer in McPhee's book who "never approach[ed] anything with the idea that it [couldn't] fail" (25). On second thought, if we were to trace the passages in Kidder's book where he describes West's frequent worry, we might realize that his is the same kind of concern that accompanies the civil engineers in the Mississippi Delta, and the same kind of caring that accompanies Pirsig's mechanic as he works on a motorcycle.

"I'd been living in fear of VAX for a year," West tells Kidder, explaining how that fear was resolved when, despite having read all the technical information that had been published on the new computer, he actually got his hands around one. West examined this VAX carefully, pulling circuit boards out one by one and tracing the pathways that the Digital Equipment Corporation engineers had laid out in copper and silicon. West found the design cumbersome. He thought it expressed the conservative, "bureaucratic style" of Digital (32). Seeing Digital's machine, West came to believe that the Data General offering to come could be made for much less cost than the VAX, while keeping comfortably on par with it in terms of power and speed.

The Eagle had been conceived and sold to management as protection in case the North Carolina FHP group failed to come through with the computer that Data General was officially backing. Eventually, Data General realized that the FHP project would go way over schedule. West's convincing the company to take "insurance" out against such a happening turned out to be a smart move, though it meant that West would have to make good on what he had promised when Data General came around to cash in their policy. Kidder continues:

> On the evening after West heard the news about North Carolina, nightfall brought no relief. The game of what's-the-earliest-date-by-which-you-can-prove-you-

won't-be-finished scheduling had been switched on West. Or he had switched it on himself; there was no essential difference. The debugging wasn't going well, and West had a wild air, as if his office were a cage.

He started out talking with his hand in his lap, keeping them busy by twiddling his thumbs. His hands kept getting away, though. He pushed back his hair. He drove his index finger up under the bridge of his glasses. He made fists and his fingers exploded outward. "I was selling insurance before. Now it's the big crap shoot, all on one number. Now I gotta get way out on the edge, full of anxiety about the company falling into a revenue hole if it's not there by April—ten thousand jobs on the line, and I gotta pretend everything's fine—and there's a lot of pressure in that. I can't afford to appear too scared around here. I don't talk about it. In the first place, no one outside of here is interested, and I can't talk to people around here and say, 'Here's how I'm manipulating you.'

"Carman [Carl Carman, Data General's vice president] says the company's in a lot of trouble if it's not there by April. Suppose I quit? I could just say, 'F—— it,' and . . . I'm not gonna do the next machine. I'm going to give somebody else a chance to fail. I'm going to get totally out of computers."

West stopped once in this long, unusually bitter monologue to say: "No, we wouldn't have a disaster. We'd back and fill." He seemed to be saying that he had to *make* himself believe that dire consequences would ensue if his team missed its deadline. In a moment, his reason seemed clear. "It just gets so scary I can't even talk about it. I may have to take Rasala into the lab and work on that thing myself twelve hours a day. When you're doing that, you carry it with you everywhere you go. At some level purely me faces me. I better be up here, just crackerjack every morning, fixing that thing. Every morning I gotta wake up and think, "Oh Christ, can I do it?'" West took hold of the arms of his desk chair, as if he were about to get out of it and head for the lab right then. "Rocking back here in my chair and talking about doing it is one thing, but it makes me worry. It gives me a nauseous feeling, because I'm not doing it." (133-34)

Although West may not have been "scared green," to use the words of the engineering professor in the McPhee essay, he must have felt the same kind of overwhelming responsibility for lives that the Corps feels, having "ten thousand" livelihoods suddenly in his hands. Remember too, West is a man who thrives on risk and thrills. But worry gnaws at him, so much so that his secretary, Rosemarie Searle, notices that over time West grows "skinnier and skinnier before her eyes, as if the job and all [its] planning were somehow consuming his flesh" (178). Near the end of the project, Kidder describes West's weight loss again:

> These nights, when West got home, he headed for his living room, and settled into the corner of an old beige couch, always the same corner. His pants looked baggy on him now, bunched up around his waist, as if pleated. He lay back into the cushion, staring straight up at the ceiling, and sweeping his hair back with one hand, brought a cigarette up to his lips with the other. (231)

Even after the project had wrapped up, Kidder notices further weight loss: "West kept on losing weight. He was tired, and he was preparing himself for a large change" (280). Somehow the worries and fears that West held within himself, the responsibility he had shouldered for seeing the Eagle project through to its completion, and the caring for those employees of Data General whom he perceived to hold him accountable for their livelihoods—all of these seem to exact a portion of West's strength. The man whom we met at the beginning of the book, the man that seems so filled with a zest for living, has been beaten down a bit by the time the story ends. He'll bounce back, we are sure. But, the cost of engineering excellence does seem high.

A lot of West's worry no doubt comes from the nature of his job: managing a bunch of creative, and in the cases we've seen, artistic, engineers who are driven by perfection, by excellence, and by a passion for their work. At times it seems these traits are at odds with the company's pursuit of a profit. Indeed, this is one of the themes in Kidder's book that rings true to Florman. Describing the story, Florman writes, "This need to stop striving for perfection—to say at some point "OK, it's right. Ship it."—is a bittersweet aspect of the engineering experience" (*IE* 111). A "persnickety profession," Florman calls engineering, remembering the tale of how as a young engineer he ran into an inspector who would change Florman's understanding of technical goodness (141). In this story, Florman's construction company was erecting a building. They had used a number of discolored bricks to construct the building's front facade. Because of these imperfect bricks, the building inspector was unwilling to sign off on the project. In fact, he had ordered the entire facade torn off and replaced, citing concerns that these discolored bricks were improperly fired, and therefore, susceptible to water damage and possibly disintegration. Rather than comply with what seemed an excessive order, Florman's company called in several specialists, including an engineer from the brick manufacturer, another engineer from a brick trade group, and a third engineer who had designed the structure in the first place. All three engineers agreed that although the color was off, the bricks were perfectly safe and no more porous than the bricks of the normal color. The building's architect did not find the discolored brick objectionable, either, to the overall aesthetics of the building. Still, the inspector held fast to his complaint that the bricks were outside of "the permissible variation," insisting at least "that some penalty be assessed." Florman says that the building's owner, the Catholic Archdiocese of New York, referring to a higher authority, concluded "that in the nature of things bricks should be expected to come out of the kiln with slight variations, and that the inspector was looking for an unreasonable degree of precision, a perfection to be found only in heaven" (143-44).

So it is that West also must make decisions that steer his engineers away from the pursuit of perfection. Giving up that pursuit may be one of the most difficult adjustments a new engineer makes in the transition from school to work. Florman says, "Suddenly we find ourselves under the constraints of time and money" (*CE* 70). Especially at Data General, where probably half or more of the engineers on the Eagle team were new recruits, and where the project itself was on an extraordinarily tight deadline, the engineers felt these constraints. Kidder describes his conversation with one Data General engineer, who,

> later on . . . , would concede that the managers had probably known something he hadn't yet learned: that there's no such thing as a perfect design. Most

> experienced computer engineers I talked to agreed that absorbing this simple lesson constitutes the first step in learning how to get machines out the door. Often, they said, it is the most talented engineers who have the hardest time learning when to stop striving for perfection. West was the voice from the cave, supplying that information. (120)

West himself seems engaged in a struggle between perfectionism and pragmatism. Kidder visits his home on at least one occasion. It is an eighteenth-century farmhouse whose structure had been well beyond plumb until West lovingly restored its straight walls and ninety degree corners. The restored kitchen "cabinets looked perfect; how patiently and carefully he must have worked to fit them," Kidder writes. His first house was so much smaller and newer than the farmhouse would be that it couldn't possibly live up to the sign which announced from his workshop wall: "The appreciation of pleasing decay is an important one because it is so often neglected." West's workshop is anything but a picture of decay. Everything is stowed shipshape: over here sit jars of hardware all labeled and arranged; over there rest several old but well maintained woodworking machines . . .

> "A window on West's soul," theorized an old friend of his, speaking of this basement. Need a pencil sharpener? There was one in every chamber, right where you wanted it to be. Some music? A couple of loudspeakers sat on shelves in corners of the machinery room. A phone? There it was. A chair? One for every mood. Beer? The old refrigerator at the front corner of the front chamber was fully stocked. A hammer? Practically every kind ever invented right in its place. (173)

If West had worked on old motorcycles, you'd expect that he would get along fine with Pirsig's narrator.

West's perfectionism did not seem to carry over to work. Kidder asks how the basement workshop could possibly belong to the same "man who wrote on his Magic Marker board at work, 'Not Everything Worth Doing Is Worth Doing Well.'" Kidder had asked West what this meant, and West, translating, said,

> If you can do a quick and dirty job and it works, do it . . . . There's a whole lot of things you gotta do to make a successful product. The technological challenge is one thing, but you can win there and still have a disaster. You gotta give 'em guidelines so that if they follow them, they're gonna be a success . . . . No bells and whistles . . . . You tell a guy to do this and fit it all on one board, and I don't want to hear from him until he knows how to do it. (119)

Several examples from the Kidder book show this philosophy in action. West's management style, for instance, goes something like this: "If you can't get what you want from some manager at your level in another department, go to his boss—that's the way to get things done." It is a style that Ed Rasala and another hardware engineer, Ken Holberger, learned from West and take for their own. "'It doesn't matter how hard you work on something,' says Holberger. 'What counts is finishing and having it work.'" It is a style that says, shun politeness when the engineers you are speaking with "aren't making good, relevant sense" (190-91).

Another example of West's philosophy comes after a long session of tracking down a particularly irksome problem in the computer. The problem took three troubleshooters, working overlapping shifts of ten to twelve hours each, several days to identify. Kidder devotes almost an entire chapter to their effort because it demonstrates the tenacity needed to isolate this kind of computer bug, one that is "hard to find and easy to fix" (208). Working in the pre-dawn solitude of the basement at Data General, one troubleshooter by the name of Jim Veres eventually discovers the problem after pursuing it by way of an inelegant approach. In what Kidder describes as the equivalent of "searching every luggage locker at Kennedy Airport," Veres has the computer print out every line of the diagnostics program that keeps tripping it up. A long strip of computer paper results, which, Kidder says, could hold "a fairly detailed description of American History from the Civil War to the present" (207). Looking at each and every line, Veres finds the error. In essence, the computer was sending one instruction to the processor before the preceding instruction had been executed, causing the computer to jam like the keys of an old typewriter at the fingers of an over-dexterous typist. Fixing the jam was simple enough. The engineers would delay the second instruction slightly to allow the first one to finish. The name coined for this repair comes straight from West's philosophy:

> The solution takes the material form of a circuit called a NAND gate, which reproduces the "not and" function of Boolean algebra. The part costs eight cents, wholesale. The NAND gate produces a signal. Writing up the [Engineering Change Order], Holberger christens this signal "NOT YET." He's very pleased with the name. Schematics he's seen from other companies use formal, technical names for signals. The Eclipse Group, by contrast, looks for something simple that fits and if they can't come up with something appropriate they're apt to use their own names. "NOT YET" perfectly describes what this signal does. That's the Eclipse Group's way, Holberger notes. It's the general approach that West has in mind when he says, "No muss, no fuss." It's also a way—a small one, to be sure—of leaving something of yourself inside your creations. (208-09)

Kidder finds yet another example of the banishment of perfection in the story of Josh Rosen. Rosen had come to the Eclipse Group by way of Data General's Special Systems Division, where, Rosen says, he was "*the* star" performer (214). "Only twenty two," Kidder writes, Rosen "had done it all—except that he had never helped to build a commercially important, big and brand-new computer" (217). An opportunity arose for him to do just that in the Eclipse Group and he took it. Not long after he joined the group, Rosen came to understand that its star position had been filled already by Holberger, and that the management practices employed by the group, from West to Rasala to Holberger, would work against his desire to "pursue pure technical excellence." It was quite unlike the atmosphere in place at Special Systems. There, he had been encouraged to strive for perfection. Now, he would find himself confronting Rasala, who clearly had things other than technical perfection in mind, things like finishing the task at hand.

> Something of a perfectionist, [Rosen] felt offended when he was told to perform quick-and-dirty repairs. Rasala, who had the job of enforcing haste, felt that

> Rosen might design the ALU forever if he let him. He took seriously Rosen's casual, digressive talk about other ways the thing might be done, and he really dreaded it. "We can't think about that," he would often snap when Rosen came to him with some new ideas. Rosen would walk away to contemplate Rasala's "sheer rudeness." They had almost nothing in common. One was big, gruff, athletic, and intent on getting the machine out the door on time. The other was of a more delicate sensibility, and eager to make comely designs. (215)

Perfection costs. It costs time. It costs money. West's team of engineers had neither time nor money to spare. So, adopting a "quick-and-dirty" style to completing tasks made sense for the managers working under West. This style rewarded mavericks and independent thinkers with results. One incidence of this style was in the way that West and Wallach, working together back at the beginning of the Eagle project, were able to make additions to the Eclipse instruction set while arranging for the request to add these instructions to come from elsewhere. Kidder writes, "Wallach would bring West an idea for a new instruction. West would say that it looked like a win . . . .Wallach knew what that meant. If the wrong people saw this new instruction in the spec, it might cause a stir." A new instruction that did not match the Eclipse instruction set would dress the Eagle computer in the robes of a "challenger to the FHP—which it was." To avoid raising this suspicion, Wallach had to befriend the programmers in the System Software group and get them to request that the new instruction be added to the Eagle's instruction set.

> Wallach went on: "A lot of things we did were unique to that environment. It's clear they weren't always the way things should be done."
>
> "But you enjoyed doing things that way?" [Kidder] suggested.
>
> "We all enjoyed it," he said. "Anytime you do anything on the sly, it's always more interesting than when if you do it up front." (83)

In another similar instance, Holberger is looking for time on the computer, which toward the end of the project, was being consumed more and more by the programmers writing applications programs for the new machine. Rather than try a direct approach, Holberger slyly writes a message that he posts to all terminals saying that the computer was about to crash. All users, the message states, should shut down their terminals immediately. In response to this message, enough users log off so that Holberger finds room for his own program to run. "Some engineers just go on working, he notes with amusement. 'The cynical and the jaded,' he thinks . . . .'I have the feeling that's the kind of behavior West approves of'" (222).

Kidder practices what seems to be a similar indirect approach to developing West's character. Much of what we learn about West comes by way of Kidder's interviews with the book's other characters. A cautious reader might ask if this was a technique which Kidder knowingly employed to make West appear larger than life, or if West's leadership was so effective that he did in fact strongly influence his co-workers. Assuming that the latter is the case and West is the kind of leader that Kidder portrays, in what ways does West reflect Florman's idealized engineer?

In *The Existential Pleasures of Engineering*, Florman writes that one of the factors holding engineers back from leadership positions is their "failure to recognize that life is complex" (27). In the previous chapter we discussed the mechanic's view of the world. This view seeks unambiguous solutions to problems that can be cleanly defined. The social, cultural, and political ills of the world do not lend themselves to solutions of the formal, scientific kind that are so familiar to engineers. Later on in this book, Florman says that engineers could learn something about the world from politicians. Despite the negative association the public has always felt toward their profession, politicians recognize that the world moves in response to the "fears and ambitions that motivate the average man." Adding this understanding along with a measure of subtlety to their bag of skills could give engineers a better "say in the way things are handled, and this would probably be most beneficial to everyone." Sophisticated engineers could then "move away from their drafting tables to infiltrate society as leaders of corporations, universities, government agencies, and community groups," where they could make even bigger contributions to the bettering of society (38).

In *Blaming Technology*, Florman writes about technology and its relationship to the tragic view. Here again Florman says that ambiguity fills the world, that modesty marches beside vanity, that daring balances circumspection:

> The fate of Prometheus, as well as that of most tragic heroes, is associated with the concept of *hubris*, "overweening pride." Yet pride, which in drama invariably leads to a fall, is not considered sinful by the great tragedians. It is an essential element of humanity's greatness. It is what inspires heroes to confront the universe, to challenge the status quo . . . .
>
> The tragic view does not shrink from paradox; it teaches us to live with ambiguity. It is at once revolutionary and cautionary. *Hubris*, as revealed in tragic drama, is an essential element of creativity; it is also a tragic flaw that contributes to the failure of human enterprise. Without effort, however, and daring, we are nothing. (190)

In *The Civilized Engineer*, Florman says that "history reveals among engineers a free-thinking, pragmatic streak of independence" (53). The best engineers question convention. They demand that reason outwit tradition. Florman goes on to compare "the characteristics of a good manager—a feeling for people, politics, and the bottom line—[to] . . . the characteristics of a first-rate creative engineer—a feeling for numbers, theorems, materials, and spatial relationships" (122). These two endeavors, he says, seem to exclude one another. But he allows that the line staked out between them can be marked off by all varieties of engineers, "from the solid, useful, technically adept engineers at one end to the socially involved, culturally sensitized engineers at the other" (213). Florman goes on to say that "the implication that engineering consists of precise calculation while 'judgment' is left to another class of person is inaccurate; further, it is demeaning to a profession that has always stressed art, imagination, and wisdom at least as much as exactitude" (162-63).

Finally, in *The Introspective Engineer*, Florman says that "the 'can do' attitude is deeply ingrained in the engineering psyche" (91). For the good of society, he says, "more than ever we require leaders who understand engineering, and engineers who are capable of being leaders." And as for the profession of engineering, Florman writes that it is clearly today "yearning for something better and more noble" (166).

These characteristics—an appreciation for life's complexity and a willingness to employ stealth in grappling with it, thrown together with equal measures of daring, caution, and judgment, along with a feeling for people, a bit of hubris, and a longing for a better world—are exactly the traits that West exhibits in his own life. In the pragmatic world of engineering, West simply wanted to "see how complicated things happen" (Kidder 175). He eschewed a blind love for technology:

> West didn't like digital watches particularly. Anyone who dared to consult such a chronometer and in his hearing say, "The exact time is . . . ," could expect to receive the full force of his scorn, for being such a fool as to think that a watch was accurate just because it had no hands . . . .
>
> West didn't seem to like many of the fruits of the age of the transistor . . . . He spoke about the rapidity with which computers became obsolete . . . . One winter night, at his home, while he was stirring up the logs in the fireplace, he muttered, "Computers are irrelevant . . . ."
>
> West had known . . . the joy derived from mastering machines, both building and repairing them . . . ."I can fix anything." What the thing was, whether a car's engine or a computer, did not matter; but since computers were among the most complex of all man-made things, they had always seemed to him, he said, to pose interesting challenges. (180-81)

With equal aplomb, West grabbed the chance to master another complicated endeavor, that of managing a group of computer builders. While it may have been his natural inclination to strive for perfection, he realized that here perfectionism was a liability. He reached decisions that could never be popular, he listened to the voice of instinct, and, always, he made himself believe that the thing he had set out to do could be, and would be, done.

CHAPTER 6

CONCLUSION

I am reminded of D. Keith Manno's review of *The Existential Pleasures of Engineering*. Manno says, "At no point can we guess how an engineer functions" (570). However, Florman himself says that in writing the book it was never his intention to "describe in any detail what it is that engineers do" (*EP* x). He was interested more in the feelings associated with engineering. He wanted to demonstrate that engineering was a creative undertaking. Manno criticized Florman for relying too much upon "a literate bibliography" to accomplish these aims, rather than drawing from his own experiences as an engineer (570).

Not every engineer's experience is the stuff of literature, however. Florman recognizes that engineers need to rely upon artists and writers to help them achieve an artistic or literary expression of their craft. With *The Existential Pleasures of Engineering*, Florman began his search for this expression. Twenty years later, with the publication of *The Introspective Engineer*, Florman looked back to find several books having been written about technology, but not nearly in the number that Aldous Huxley had predicted. Even so, science writing had advanced far more in this period, Florman says, which is cause for hope that a rise in technology writing may not be far off.

Looking through an anthology of science writing, one finds a mixture of scientists and non-scientists alike writing about science (Bolles). However, no engineer is to be found among the twentieth-century writers whom the collection contains. Science has traditionally been the more visible of the twin endeavors labeled "science and technology." Science's good image, Florman says, " is related to the purity of the search for truth, whereas the ambiguous image of engineering is related to the making of things" (*IE* 132). When high-order technological achievements are underway, Florman says it is science to which the media give credit; when technological disasters unfold, he says it is engineering to which the media lay blame (131).

Perhaps this image perpetrated by the media, whether intentional or not, has discouraged those authors who would be inclined to write about engineering and technology. Maybe writers who are attracted to engineering come to find that science is the focus for positive press, and so they direct their efforts that way. Perhaps the perception that the engineering world is cold and heartless repels writers. Unlike the cowboys and soldiers that Florman mentions, engineers have no passions, no fears, no guts, and no glory.

Obviously that is not true. We have found among the three literary works studied here not only passion and fear, but creativity, cunning, danger, caring, and uncertainty—the very essence of literature. We have met engineers who have cared deeply for what they have done. Some sought in their work adventure. Some sought understanding of the natural world. Nearly all the engineers we met sought some kind of expression of themselves in their achievements, which, without the interpretation of these writers, could have remained hidden to all but a specially-trained few.

And then there is the beauty and elegance we have found. Sometimes beauty has been visible on the surface, as in the Old River Control Auxiliary Structure. Sometimes it was uncovered only after looking below the surface. There was underlying beauty and elegance to be found, for instance, in that oddly shaped BMW motorcycle engine, or in the parallel jetties at the mouth of the Mississippi, or in the cantilevers of the Firth of Forth Bridge. Beyond physical expression, there was beauty and elegance to be found in the logical constructs of software engineers, or in applications of the language of Boolean algebra.

But aside from beauty and passion, engineering is a practical endeavor, as Florman says. Writers may not be all that interested in the beauty of its works. If not, though, surely they are interested in the creative process, or the adventure and thrill of "flying upside down," or the anxiety that accompanies the fear of failure (Kidder 117). There is plenty of wholesome material of this kind to be found in the engineering and technological communities. McPhee, Pirsig, and Kidder show us that.

There is always the possibility, of course, that these authors, because theirs is a gift of storytelling, may have embellished mundane events with an editorial polish. But two of the books were written in the style of literary journalism, and the third, according to its author, Pirsig, was "based on actual occurrences" (Author's Note). This provides a certain degree of confidence that these writers have portrayed their subjects in as accurate a light as possible. Much of what Florman writes can be matched up directly with the writings of the other three authors, as we have shown here, providing further assurance that the accounts of these engineering endeavors are factual.

These works about engineering elevate the accomplishments of engineering to their rightful place alongside humanity's other achievements. Engineering deserves a Shakespeare, Florman says. Engineers themselves have been mute when it comes time to praise their profession—they've been too busy expressing themselves with concrete, or metal, or silicon, to bother to try to get the words right. Yet, thanks to the efforts of pioneering writers such as McPhee, Pirsig, and Kidder, and the efforts of Florman in championing their work, the day may not be far off when we will witness the fulfillment of Florman's longing for a literature of technology.

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