Also by Samuel C. Florman
Engineering and the Liberal Arts (1968)
Blaming Technology (1981)
The Civilized Engineer (1987)

THE EXISTENTIAL PLEASURES OF ENGINEERING

Samuel C. Florman

SECOND EDITION
with four additional chapters from
Blaming Technology and
The Civilized Engineer

A THOMAS DUNNE BOOK

St. Martin's Press New York

14. THE ENGINEERING VIEW

(from The *Civilized Engineer*, 1987)

What *is* an engineer? The National Research Council's Committee on the Education and Utilization of the Engineer recently framed a definition:

> *Engineer*. A person having at least one of the following qualifications:
>
> a. College/university B.S. or advanced degree in an accredited engineering program.
>
> b. Membership in a recognized engineering society at a professional level.
>
> c. Registered or licensed as an engineer by a governmental agency.
>
> d. Current or recent employment in a job classification requiring engineering work at a professional level.[1]

Very well, then, what is *engineering*? Again the committee provides an answer:

> Business, government, academic, or individual efforts in which knowledge of mathematical and/or natural sciences is employed in research, development, design, manufacturing, systems engineering, or technical operations with the objective of creating and/or delivering systems, products, processes, and/or services of a technical nature and content intended for use.[2]

Quite a mouthful, and not really an improvement on Thomas Tredgold's classic definition of 1828: "Engineering is the art of directing the great sources of power in nature for the use and convenience of man."[3]

Engineers, as viewed by the public and as confirmed by self-image, constitute a single profession. Yet the roughly 2.5 million American engineers (1990s figure) form a strikingly diverse group. First of all, they differ by specialty: electrical/electronic, mechanical, civil, industrial, chemical, aero/astro, and other, including mining, computer, manufacturing, petroleum, marine, agricultural, nuclear, bioengineering, environmental, ceramic, metallurgical, and materials.

Contrasts appear also when the profession is categorized by type of activity: research, design and development, R and D management, other management, teaching, production/inspection, and other, including consulting, reporting, statistical work, and computing.

And even these categories do not begin to hint at the diverse social roles that engineers play. Consultants, researchers, and academics; entrepreneurs and corporate executives; public works officials and other civil servants; a wide variety of quasi-professional employees—the spectrum is broad and getting broader as computer engineering attracts a new breed of bearded blue-jeaned mavericks. As for politics, there are right-wing engineers and left-wing, hawks and doves, progrowth and antigrowth, pronuke and antinuke. Some engineers are ardent environmentalists; others are hostile to environmentalism. Most engineers, like most citizens, hold many different opinions, some of them inconsistent and subject to frequent change. Needless to say, there are a variety of religious beliefs and ethnic affiliations. Engineering used to be something of an all-male association, but this is no longer the case.

Even before the profession exploded into a myriad parts, engineers had difficulty in getting together—or rather staying together—socially and institutionally. One might think that an engineer would be the quintessential organization person, but the truth is otherwise. In the United States the splintering phenomenon started early and continues to this day. There is no powerful, central, national engineering organization comparable to the American Medical Association or the American Bar Association, and there are good reasons to believe that there may never be one.

Since the founding of the American Society of Civil Engineers (ASCE) in 1852, the main organizing thrust of the engineering profession has been along the lines of technical specialties. All efforts at profession-wide federation have ended in failure. The latest attempt—the American Association of Engineering Societies (AAES), instituted in 1979—almost succumbed to intramural feuding, and exists today as a coordinator of loosely affiliated member societies. "When we started," says a member of the AAES board of governors, "we thought we would hire someone who could speak for the entire engineering community. But that was very difficult because the engineering community didn't have any discrete message."[4]

Beyond the hard facts of diversity, however, and overriding the details of definition, is there not for engineers a shared way of approaching the world, a common outlook that one might call "the engineering view?" I suggest that there is.

In seeking the essence of the engineering view it seems appropriate to begin with the scientific view. All contemporary engineers enter their profession by passing through the portals of science. In order to be admitted to an accredited engineering school, a young person must have studied science and shown an aptitude for it. To graduate from an accredited engineering school he or she must study a lot more science—and, of course, the mathematics that is an essential element of science. Indeed, the almost exclusive criterion for entering the engineering profession is the ability to "do" science and to do it well.

"Doing" science implies a belief in science, and I think it is fair to say that this belief lies at the heart of engineering. The engineer does not believe in black magic, voodoo, or rain dances. The engineer believes in scientific truth, that is, truth that can be verified by experiment.

The search for scientific truth requires that we disregard, so far as possible, our personal value systems; yet, paradoxically, this approach creates its own values. As Jacob Bronowski has written: "Independence

and originality, dissent and freedom and tolerance; such are the first needs of science; and these are the values which, of itself, it demands and forms."[5] In the same vein, Bertrand Russell asserted that "those who forget good and evil and seek only to know the facts are more likely to achieve good than those who view the world through the distorting medium of their own desires."[6]

So this is the beginning of the engineering view: a commitment to scientific truth and to the values that the search for this truth entails.

Occasionally our critics view this commitment as evidence of a lack of "soul." When one deals in hard facts it is easy for an observer to conclude that one has a hard heart. Using an even uglier metaphor, Theodore Roszak has said that scientists and technologists look at the world with "a dead man's eyes."[7] I find such criticism to be particularly irritating. There is a place in the world for poetry and sermons and for visions of "what might be" rather than "what is." But there is also a need for facts and plain-speaking. As engineers we are pledged not to engage in merely wishful thinking. We are not the grasshopper; we are the ant who knows that winter is coming. We are the grumpy little pig who builds his house out of brick while his friends play and sing "Who's afraid of the big bad wolf?" We do this because we know what the big bad wolf can do when he huffs and puffs. This does not mean that, as individuals, we cannot love poetry and approve of sermons—or even preach sermons. But, because we are committed to scientific truth, we believe that poetry and sermons alone are not an adequate foundation on which to build human society. The evidence convinces us that God helps those who help themselves. It does not follow that we are selfish. The evidence also shows that God helps those who work together cooperatively and provide for one another.

There is a fringe benefit that comes along with our familiarity with science—and with the technological applications of science—and this is that it helps make us feel at home in the world. To the extent that the forces of nature have been comprehended, and the structure of the universe revealed, we share in the understanding and this gives us some measure of contentment. This comfort—this inner peace, if you will—is a basic ingredient of the engineering view.

This does not mean that engineers are, or have any reason to be, smug. We are humble before the unknown and stand in awe of the unknowable. But we do not feel alienated, as some people say they do, by the scientific advances of our age. And our message to our nontechnical fellows is that to a certain extent this understanding—and the peace that goes with it—is available to all. Anyone who is willing to explore, however superficially, the findings of science, can share in this feeling of at-homeness in the world.

The study of science, if it is to lead to professional competence, must entail hard work, and the engineering view accepts this. Engineers believe in hard work. We demand it of ourselves and require it of those who would join our ranks. We think that hard work is somehow treasured in the scheme of things. Knowledge and understanding are precious objectives worth striving for. The quest for excellence is a virtuous enterprise that needs no rationalizing.

Although we are committed to scientific truth, there comes a point where this truth is not enough, where the application of truth to human objectives comes into play. Once we start to think in terms of utility, we must leave the placid environment of the laboratory, take off our white coats, and roll up our sleeves. We are no longer considering theoretical forces and ideal substances. We are now obliged to work with materials that are real, impure, and sometimes unpredictable. Our aim is no longer to discern absolute truth, but rather to create a product that will perform a function. And suddenly we find ourselves under constraints of time and money. To a practicing engineer the search for perfection becomes self-defeating. In *The Soul of a New Machine,* Tracy Kidder recounts how the engineers designing a computer must forego the luxury of constant refinement of their work. Instead of trying to make the perfect computer, they strive to make a good machine that they can get "out the door." They live for the moment when they can merely say, "Okay, it's right. Ship it."

If engineers are not afforded the luxury of seeking perfection, it follows that they must be willing to risk failure. Indeed, the willingness to make decisions knowing that something may go wrong is one of the most challenging aspects of the engineering experience. Engineers do not *want* to take chances. Prudence is implicit in our every undertaking. But as human societies seek to develop high civilizations, they inevitably strive to span ever wider chasms, build taller buildings and broader domes, create more sophisticated machines, and tap ever more elusive

sources of energy. Citizens say to their engineers, "Do these marvelous deeds, but be careful." Engineers accept this charge knowing full well that every time they undertake a new design they may be defeated by unknown causes. We talk lightly of gremlins and Murphy's Law, but this banter is a manifestation of our underlying anxiety.

Even the most cautious engineer recognizes that risk is inherent in what he or she does. Over the long haul the improbable becomes the inevitable, and accidents *will* happen. The unanticipated will occur. Not that it is difficult to design redundant safety features into a product—it is merely expensive. It would be a lot easier for engineers if their fellow citizens would clearly stipulate that safety should be the paramount concern, whatever the cost. But the people do not say this. They want automobiles that are affordable and attractive; they want airplanes that are light enough to conserve fuel, and power plants that will turn out cheap electricity. They appear willing to pay for relatively foolproof backup systems for space vehicles, but precious little else. In other words, people are willing to take risks, but, naturally, do not want to pay the penalty for taking those risks. In such a world it requires a certain amount of moral toughness, something that verges on bravery, to say, all right, I will take the responsibility, and if the worst should happen, I will accept the blame.

Civil and mechanical engineers are particularly vulnerable since they have to cope with the devilish phenomenon of metal fatigue. There is no completely reliable way to predict how metals will behave when subject to vibrations and erratic stresses in changeable climate and over long periods of time. Sometimes the only way to gain knowledge is by experiencing failure. The British Institution of Mechanical Engineers published a fascinating volume entitled *Engineering Progress Through Trouble.* Reading this and similar works is a humbling and frightening—but in the end exhilarating—experience. To be willing to learn through failure—failure that cannot be hidden—requires tenacity and courage.

It has been said that doctors bury their mistakes and architects plant ivy. Most experts have a way of avoiding blame by claiming that their ideas were not given a fair trial. Economists are famous for this ploy. Politicians, as is well known, never make a mistake. Engineers have no such easy evasions. Well, so be it. Somebody has to step forward to do what needs doing. We can't all sit around being critics, supervisors, and second-guessers. Thus a principal feature of the engineering view becomes the willingness to accept responsibility.

• • •

Those citizens who take on responsibility make an implicit promise to their fellows to be *dependable*. You can count on us, we say to our neighbors. We will do our very best not to let you down.

Let me be clear about what I mean by this. I do not believe that it is up to the engineering profession to decide what is good for society, to decide, for example, whether we should favor mass transit or individual automobiles, allow drilling for oil off our coasts, authorize the use of public lands for mining, or determine how much of our national product should be devoted to armaments. In other words, I do not believe in technocracy. What I do mean is that in the pursuit of goals established by the entire community, engineers should be dependable. This commitment to dependability is something that we share with all the professions. It is, in fact, the essence of professionalism and it underlies our system of accreditation and licensing. I once knew an elementary school teacher who said that whenever she wanted to make sure that a specific task would be accomplished—erasing the blackboards after class, say, or putting the blocks away neatly, or bringing in the juice and cookies—she would call upon, if possible, a redheaded boy. She didn't know why, but in her experience redheaded boys were always dependable. In my experience engineers are singularly dependable. The resolve to be dependable is another essential element of the engineering view.

Obviously, engineering is dependent upon a society that functions effectively. Most engineers now work in large organizations and participate in mammoth undertakings. Thus, they learn to value cooperation and recognize that their work requires an established social structure. This is one way in which the engineering view differs markedly from the view of the artist. A poet can be a rebel—indeed, one of the main functions of a poet is to be a rebel, to startle, and to shock. But engineering and rebellion do not go together. If the power plants are to operate and the factories to produce, law and order must prevail. In this sense engineering is conservative. Engineering depends upon social stability and contributes to it. Engineers are not likely to be anarchists or nihilists; that would be almost a contradiction in terms. There can't be any engineering in a chaotic world. But just because we believe in order

does not mean that we, as a group, are committed to any particular type of order.

It has been said that because so many engineers are employed by American industry the profession has become a tool of American capitalism. The people who make this charge conveniently disregard the many thousands of engineers who work for federal, state, and local government, overseeing the nation's vast public works infrastructure and participating in essential regulatory activities. Increasingly, engineers are playing a role in public interest organizations, and of course many engineers are academics and private consultants. Even though engineers may agree that some organization is essential, it is clear that engineers have a variety of ideas about how society should be organized.

Most engineers tend to be pragmatists rather than ideologues. Ideology, after all, does not cure diseases or provide food and shelter. As pragmatists we are constantly reevaluating our ideas about the social structure, and as we observe how things are done in Japan, for example, our interest in the possibility of change is surely piqued. But we must keep reminding ourselves that though we are dedicated to the concept of order, political ideology has no place in the engineering view. Individual engineers may be—should be—political, but they have no right to expect that their colleagues, *as engineers*, will share their partisan commitments.

Although engineering requires social stability, and engineers are rarely found among the ranks of revolutionaries, technological progress has, in fact, contributed to the growth of democracy. Democratic ideals were expressed many centuries ago, but only modern engineering has made it possible for these ideals to be brought closer to fulfillment. It may not sound impressive to say that the goal of our society is "a car in every garage," but this is merely shorthand for saying that one person is as good as another and that opportunity should be available to all. The accumulation of material wealth has made it possible to think in this vein. Printing, radio, and television have made it possible and perhaps inevitable for the democratic ideal to spread and eventually prevail. Education and culture—not just for the privileged few but for the many—have followed in the wake of technological development. I do not mean to imply that engineers sally forth each day to save democracy. But in subtle yet powerful ways their work has served this cause. People have expressed concern lest high technology bring about despotism by making it possible for the few to dominate the many. But the evidence indicates that this is not happening and will not happen. The flame of freedom, once ignited, is almost impossible to extinguish. At least this is so where technology provides people with the basic necessities of life. Poverty and hunger serve the ends of despotism, and engineering fights the good fight against these scourges.

Engineering serves the cause of democracy in another way by being in itself—in its institutions and its personality—democratic. As noted above, Jacob Bronowski has said that science requires "independence and originality, dissent and freedom and tolerance"; engineering shares these needs. And in the United States most engineers have come from the middle and lower middle classes. Engineers are not snobs. We may sometimes be dull, but we are hardly ever snobbish.

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. We can certainly hope that our seriousness will be of good quality, that we will be earnest without being morose, sober without becoming glum. Maybe we can even try to become slightly more lighthearted.

Although engineering is serious and methodical, it contains elements of spontaneity. Engineering is an art as well as a science, and good engineering depends upon leaps of imagination as well as painstaking care. Creativity and ingenuity, the playfulness of original ideas—these are also a part of the engineering view.

Since engineering is creative—persistently and energetically creative—it has quite naturally become identified with the concept of change. In the American mythos, the quality of life can be constantly improved, an outlook that both stems from, and contributes to, the engineering view. However, we are not as naively optimistic in this regard as we used to be. It is now widely recognized that not all change is for the better and that change merely for the sake of change is foolishness. Human beings, we now recognize, are resistant to extensive alterations in their patterns of life. Just a few years ago a typical vision of the future pictured puny people seated in front of glowing TV screens and taking their meals in the form of pills. What actually happened in this era of high technology was an astonishing growth in jogging, body-building, and exercising of all sorts, as well as a resurgence of interest in gardening, organic foods, camping, and do-it-yourself handicrafts. Sales of canned foods have dropped in the face of a renewed craving for fresh produce.

This urge to preserve the best of the past does not mean that the quest for technological improvement will be curtailed. It is worth recognizing that today's backpackers make grateful use of aluminum and nylon, both of which are products of energy-intensive technologies. Engineering is committed to the prospect of new discoveries, and engineers still look eagerly to ever-receding horizons. We are tinkerers at heart; we cannot keep our hands off the world. However, the over-optimism, and perhaps even arrogance, that had been creeping into the engineering view is being replaced by a more thoughtful but still enthusiastic commitment to change.

These, then, are what I take to be the main elements of the engineering view: a commitment to science and to the values that science demands—independence and originality, dissent and freedom and tolerance; a comfortable familiarity with the forces that prevail in the physical universe; a belief in hard work, not for its own sake, but in the quest for knowledge and understanding and in the pursuit of excellence; a willingness to forgo perfection, recognizing that we have to get real and useful products "out the door"; a willingness to accept responsibility and risk failure; a resolve to be dependable; a commitment to social order, along with a strong affinity for democracy; a seriousness that we hope will not become glumness; a passion for creativity, a compulsion to tinker, and a zest for change.

The reader may notice that I have not included a staple of much writing about engineering—the urge to serve humanity. Most of the engineers I know are good people but truly no more altruistic than the average citizen, and I feel it is somewhat deceptive for us to imply that this is not the case. Engineers are not missionaries. As professionals we pledge ourselves to public service, but I think this is stating the case somewhat backward. By being hardworking, responsible, dependable, and creative we end up being of service to the community, as well as enhancing our own pride and pleasure.

The reader might also notice that I have not referred to the existential pleasures of engineering. This is partly because I have already written a book on that theme. But mainly it is because the existential pleasures—the deep-down satisfactions that stem from engaging in the technological work that human beings instinctively want to do—are the reward we receive rather than the goal we seek.

The engineering view is far from the only acceptable way of perceiving the world, and I hope that engineers will be receptive to various types of experience—including the literary, artistic, and political. And, of course, I do not expect all engineers to see our profession exactly as I do. As Santayana has said: "I do not ask anyone to think in my terms if he prefers others. Let him clean better, if he can, the windows of his soul, that the variety and beauty of the prospect may spread more brightly before him."[8]

15. TECHNOLOGY AND THE TRAGIC VIEW

(from *Blaming Technology*, 1981)

House & Garden magazine, in celebration of the American Bicentennial, devoted its July 1976 issue to the topic "American Know-How." The editors invited me to contribute an article, and enticed by the opportunity to address a new audience, plus the offer of a handsome fee, I accepted. We agreed that the title of my piece would be "Technology and the Human Adventure," and I thereupon embarked on a strange adventure of my own.

I thought that it would be appropriate to begin my Bicentennial-inspired essay with a discussion of technology in the time of the Founding Fathers, so I went to the library and immersed myself in the works of Benjamin Franklin, surely the most famous technologist of America's early days. Remembering stories from my childhood about Ben Franklin the clever tinkerer, I expected to find a pleasant recounting of inventions and successful experiments, a cheering tale of technological triumphs. I found such a tale, to be sure, but along with it I found a record of calamities *caused by* the technological advances of his day.

In several letters and essays, Franklin expressed concern about fire, an ever-threatening scourge in Colonial times. Efficient sawmills made it possible to build frame houses, more versatile and economical than log cabins—but less fire-resistant. Advances in transport made it possible