

Technology, in Perspective and under Control

WE ALL SHARE the goal of humans reaching a sustainable and comfortable accommodation with each other and with the global environment. Technological, environmental, and societal factors intermingle and collide with each other as we move toward this goal. Because pressures are increasing so rapidly, I feel that if this goal is to be reached, it must be reached within our lifetimes or those of our children. In particular, I find myself concerned that a number of technological advances, each beneficial to its developers and users, will be found to have a negative impact, especially when viewed over a time scale of several decades. This article explores challenges we all face, some from technological advances, and suggests ways for an individual to make a significant difference.

Genetically, we are still the gatherer-hunters of the pre-agricultural era, but now we are operating airlines, computers, television, and robotic factories, and we have a finger on nuclear energies. Our technology rockets ahead, introducing in a year more innovation, and more global impact on the environment and civilization, than took place in a century just a few hundred years ago, or in a millennium just a few thousand years ago. This has its obvious good side, but the negatives, particularly those we don't even suspect yet, could prove overwhelming in the future. We are rapidly eliminating fellow species of flora and fauna and their habitats, and in general making unsustainable demands on the limited resources of the earth. We find robots displacing workers, new weapons arming terrorists, and improved communications being appropriated to facilitate dictatorial control. Our modern culture, our institutions, and our individual reward systems are poorly matched to the tasks of moving toward man getting along with the millions of species of flora and

by Paul B. MacCready

fauna — and man getting along with man. We have more intelligence than wisdom, and technology is evolving toward becoming our master rather than our servant.

For the past few decades most of us have accepted that we are all passengers on "space-ship earth." Recently we have realized that we are not just passengers but also crew. Still more recently we have noted that some of the crew may be very bright, but overall the crew is quarrelsome, unmanaged, and not very effective at plotting a desirable destination and a sustainable living style.

The responsibility scientifically competent individuals have for operating in a broader arena is succinctly reviewed by Carl Sagan in

Cosmos, while discussing the Library of Alexandria and the reason that science slept for a thousand years after the library's demise:

"... there is no record, in the entire history of the Library, that any of its illustrious scientists and scholars ever seriously challenged the political, economic, and religious assumptions of their society. The permanence of the stars was questioned; the justice of slavery was not."

I have no credentials for handling such broad issues — only a belief that it is appropriate to be involved in subjects you deem important rather than just those that fit comfortably into your narrow area of expertise. My connection with global challenges arose unexpectedly over the past decade. The catalyst was the development of the *Gossamer Condor* and the *Gossamer Albatross*, which in 1977 and 1979 won the Kremer prizes for human-powered flight. The motivation for undertaking those projects was simply to win the prize money, but the greater, and wholly unanticipated, result of those and subsequent projects featuring the development of unusual vehicles was to stimulate my interest in broader issues. I found myself often giving presentations at corporations, museums, and educational institutions. Preparing for these presentations, answering questions from the audience, and interacting with a wide range of new acquaintances forced me to think about how such projects fit into a broader context. Was there real value in these impractical vehicles that operated at the border of biological and mechanical flight? What is the role of competitions? Do the developmental techniques have more general validity? This thinking edged into the subjects of invention/innovation by man, evolutionary invention/innovation by nature, how our minds work, the teaching of thinking skills, and how all of these relate to civilization's challenges and future.

One insight seemed especially significant. It dawned on me that what I considered big problems, such as overpopulation, starvation, carbon dioxide buildup, the disappearance of rain forests and top soil, the fanaticism of cults, 20th-century weapons in the hands of 10th-century cultures, nuclear proliferation, and so on, were merely consequences of the real problem, the human mind, individually and collectively — how we build up belief systems, why we follow certain leaders, how we perceive present and future problems, and how we organize to resolve them. There is

no more important subject than the human mind, both to humans and to all the life forms with which we share this fragile globe.

The mind's creativity, logic, and other wonderful attributes make us optimistic about the future, but these attributes are severely limited by negative characteristics, particularly the narrowness of our thinking. Our mental blinders are particularly pernicious because we are usually unaware of them. Inputs to and processing by our brains involve a filtering from prior experiences. On the plus side this results in efficiency: we see patterns from just a few clues and waste little time on unproductive avenues. On the minus side, this narrowing or prejudice closes off options. A simple example is when we ask for the solution to a problem. That innocuous word "the" immediately narrows our thinking, and we instinctively search for a *single* solution. Our language, and all our cultural institutions, narrow the way we think in some respects while broadening the way we think in others. We do not realize how thoroughly our culture molds us; we believe we are the puppets of our actions, not comprehending how our individual backgrounds pull our strings. We usually do not appreciate the experiences of others or perceive that if we had a similar upbringing we would probably think and act as they do. We also instinctively assume the human perspective on every subject and thus manifest a conceit for our human ability and destiny. We worry about the demise of rain forests primarily because we may lose some potential medical discovery or because an increase in the CO₂ problem may imperil civilization's convenience. We have a hard job perceiving ourselves as relative newcomers to, and fellow animals in, an interdependent world of delightful biological diversity.

Before exploring actions that an individual might take for upping the odds on a comfortable global future, there should be an assessment of the problems and their underlying causes. There is no dearth of information on the subject of pressures on the environment. There are television documentaries, newspaper articles and editorials, the annual *State of the World* book from the Worldwatch Institute, popular books and articles by authors such as Carl Sagan, Isaac Asimov, and Stephen Jay Gould, and many contributions to the professional literature. Some of the same sources, as well as many others, also treat the subject of technology's confronta-

tions with ethics and social institutions, confrontations that directly produce pressures on civilization and hence also pressures on the natural environment.

People who viewed the future with alarm, such as Malthus, have in the past been wrong — or at least premature. But there are limits to the carrying capacity of the earth. A mere 100 years ago, after 3.5 billion years of life on earth, the human population reached 1 billion. Now, in the next 10 years or so we will add another billion to the present 5 billion, and the growth will not stop. In addition, there are increasing per-capita expectations, demands, and consumption. Further, pressures from human activity are quickly distributed around the globe — by advanced communications and travel, as well as by atmospheric and oceanographic transport. A simple analogy to the problem of limits is to represent the earth as a balloon. Each breath, each new pressure, makes the balloon more beautiful, and experience with all the prior breaths shows there is nothing to worry about. The pessimist who says, "Don't put in another breath," or "Don't put more stress on the global ecosystem," is continually shown wrong, but will one day be right. The wisdom of the past indicates that growth and increased pressure are not to be feared. But we have only *one* balloon and no experience with others, and we cannot afford to make a mistake. Our predictions about popping must be based on rational evaluation rather than on experience; unfortunately, the stresses are building so fast that the wisdom of the past is an inadequate basis for solutions.

In the past, agricultural and mining cultures often consumed their resource base. Then, whether or not they had listened to their "Malthus," they collapsed or moved elsewhere. For our present global civilization, which mines nonreplenishable resources and strains the carrying capacity of the atmosphere and oceans, there is really no "elsewhere." Inevitably, civilization will reach an accommodation with this limited earth. The question is whether this accommodation will be comfortable or catastrophic. Incidentally, some people think of space as the safety valve to let future generations decrease the pressure on the earth, but I have never met anyone who seriously thought that a century from now space will actually absorb even 1/100 of a percent of the annual population increase. I believe that the challenges and solutions for us all are tied to this fragile globe and that

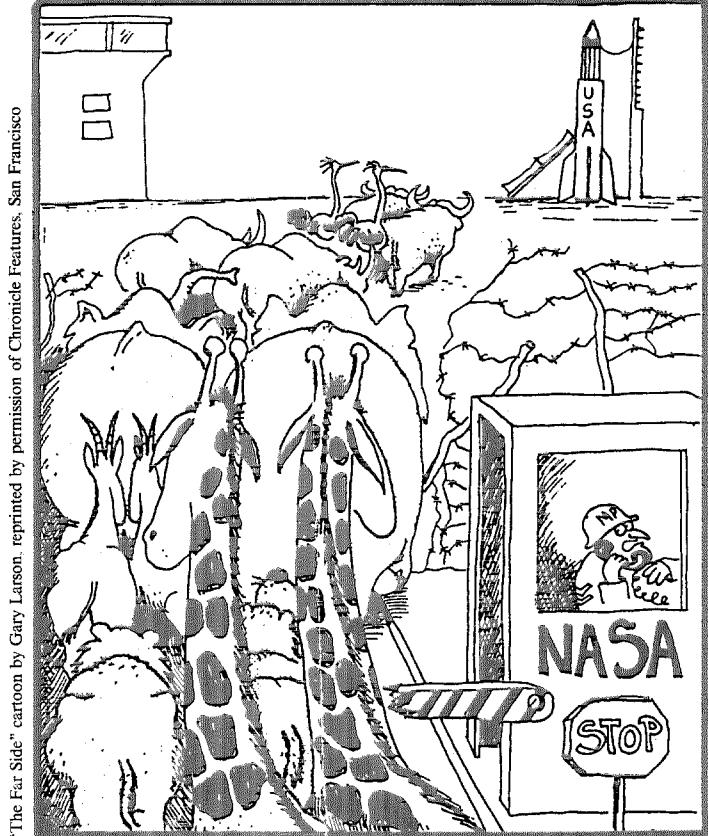
space technology is a tool and a catalyst for broadening perspectives; it will not provide an escape during the next few decades, before the pressures become uncontrollable.

Some of the most troublesome future challenges posed by advances in science and engineering relate to ethics and philosophy. Albert Einstein put it depressingly: "Technological progress is like an axe in the hands of a pathological criminal." In particular, robotics, artificial intelligence, and medical breakthroughs now pose ethical questions beyond the reach of even a mythical Solomon's wisdom. For example, robotics and the artificial intelligence revolution assure that in several decades the material needs of this country can be met by relatively few workers. Will there be a satisfying role for the unnecessary workers? Will the haves and the have-nots become more polarized? What about the dangers to the democratic system as new scientific, interactive studies of audience response give the charismatic politician even greater impact through television?

As man increasingly becomes master of life and genetic evolution, the questions get

Paul MacCready poses with the solar-powered Sunraycer, which his company, AeroVironment, designed in collaboration with General Motors and Hughes. The vehicle, which will compete in a 2,000-mile race in Australia at the beginning of November, scored the lowest drag coefficient ever recorded in Caltech's 10-foot wind tunnel.





"The Far Side" cartoon by Gary Larson, reprinted by permission of Chronicle Features, San Francisco

"Something big's going down, sir . . . they're heading your way now!"

tougher. Should we encourage procreation in countries where starvation from overpopulation and a dwindling resource base await the children? Should we use expensive and extraordinary means to prolong the lives of terminally ill patients? Is the creation of test-tube babies to be welcomed? Should information from amniocentesis be used as the basis for terminating a defective embryo? How do we respond as developments in artificial intelligence, robotics, gene splicing, and organ substitution blur the dividing line between what is natural and what is technological? Our culture is ill-equipped to comprehend and assimilate, or plan and control, such technological benefits. Our political, economic, social, and religious institutions have great inertias and respond slowly to sudden new pressures.

No single technological advance will be the key to a safe and comfortable long-term future for civilization. Rather, the key, if any exists, will lie in getting large numbers of human minds to operate creatively and from a broad, open-minded perspective, to cope with the new challenges. I have some optimism because I think minds can be opened

more readily and quickly than is usually assumed. The minds of scientific and technological professionals are especially important because of the leadership roles of such people, but in the long run it is the minds of young students, those who will be the solvers or sufferers, that are critical. It is most important that students learn how the human mind works and that they develop broad thinking skills, not just the ability to store facts and react. Schools in the United States are edging toward fostering the important but hard-to-quantify skills, attributes, and abilities such as creativity and problem solving, seeing two (or more) sides of an issue, realizing why others perceive differently, having healthy skepticism and an ability to sort out fact from fiction, comprehending the big picture and the dominant factors, developing an instinct for questioning, and evaluating the consequences of actions. All of these promote an enthusiasm for both the natural and the man-made world. I think they are essential for giving civilization a chance; fortunately, because they also help individuals to be happier, to be more productive, and to make more money, such training can be "sold" to schools, individuals, and businesses.

Such thoughts suggest that one socially useful action for an individual is to support (and use) organizations and activities that are directed at stimulating thinking and broadening perspectives. In the last few years in an unsystematic way I have directly encountered many groups that deserve support, and I will cite a few here. I am aware that many other worthy ones exist. One thinking-skills training program that provides especially simple but ingenious techniques for deleting mental blinders was developed for schools and businesses by Edward de Bono of England. Innumerable courses in creativity are available, probably all useful, but the de Bono method deals with broader skills than most and, relatively independent of the IQ or the socioeconomic circumstances of the trainee, appears to yield surprisingly high returns per hour invested. The program doesn't tell you what to think; it's somewhat like cleaning your glasses — you see better, but you still determine what to do with what you see.

The OM Association — formerly known as Olympics of the Mind — is another organization that effectively fosters thinking skills. This rapidly growing group cooperates with more than 5,000 schools, challenging youngsters to work together in hands-on activities

that emphasize teamwork and divergent thinking in friendly, humorous competitions. Teams select subjects from fields such as engineering, computers, art, and history, among others, and participate in state and national competitions. OM, which receives support from IBM, was featured in an episode on Bill Moyer's "Creativity" television series.

Another effective group is the Lindbergh Fund, a foundation dedicated to perpetuating (through grants and symposia) the mission to which Charles Lindbergh devoted the last half of his life: seeking a balance between technology and nature. Incidentally, the wide-screen IMAX film, *On the Wing*, sponsored by Johnson Wax and the National Air and Space Museum, suits the foundation's philosophy by dramatically showing the connection between the evolution of natural flight and the evolution of aircraft. Our flying replica of a giant pterodactyl (*E&S*, November 1985) was created to fit into both portions of the film. We also felt that this dinosaur-like flying reptile could harness the enthusiasm for dinosaurs that all youngsters have, an enthusiasm that can help lure a few more people into science or at least into comprehending evolution.

I am involved with several other groups that broaden people's perspectives. One is the International Human Powered Vehicle Association, which stimulates invention by setting up races of low-power, high-technology vehicles (land, water, or air) without the stifling influence of rules. Others are CSICOP (the Committee for the Scientific Investigation of Claims of the Paranormal), and a related group that has been meeting regularly at Caltech, the Southern California Skeptics. These are dedicated to sorting facts from fiction, to investigating and providing, if possible, rational explanations for unusual observations, and to serving as a resource of rationality for members of the media willing to draw on their expertise. These groups explore the mechanisms of gullibility. Magicians are especially effective members because they have excellent insight into techniques of deception and the prevalence of self-deception. In fact, if magic clubs were organized in every high school, millions of students would benefit from first-hand knowledge of how gullible we all are — a humbling lesson in how the mind works.

Beyond supporting organizations that work directly on developing broader thinking,

individual scientists and engineers can take other actions as well:

- Ask yourself the probable 20-year consequences — good and bad — of the scientific or technological field you are working in.
- Organize a session at the next national meeting of your professional society to focus on the ethics and broad consequences of your field. Perhaps a joint session with a non-technical society would be useful.
- Write letters to the editors of newspapers and magazines when you think news stories, articles, and editorial discussions are moving in the wrong direction.
- Be willing to devote time to making presentations to school boards and textbook committees. In California a few spirited scientists and engineers have recently been instrumental in reversing the "dumbing down" of textbooks. Most of us have been too lazy to be concerned.
- Volunteer Saturday mornings to teach in special science programs, to help a computer club, or to get young people to museums or out on nature hikes.
- Organize visits to your technology company by school children, garden clubs, religion classes, art groups, and so on — all sorts of people who should become more familiar with technology even if they are not involved with it professionally. Never forget that people outside of technology provide the main resources, votes, and standards that determine technology's economic viability.

Establish colloquia, salons, or informal once-a-month breakfasts where people feel free to discuss and argue about "big" and controversial issues (such as "what is man?," "religion vs. science," "man's responsibility for species extinction," "global survival," "communications in a 21st-century democracy,") I have found that technologists are often eager to discuss such issues but rarely find themselves in circumstances where such discussions are generated.

In the end, technology does not exist by itself. Rather, it fits into a global, ethical framework, where serious, complex questions and concerns arise related to the survival of humankind, nature, and civilization. It is appropriate that those of us involved in the development and use of technology devote attention to consequences and solutions (whether or not the solutions involve technology). We must not succeed in our various short-term goals and find that we thereby lose the grander game. □