HARDIN'S LAW: AN ENGINEERING PERSPECTIVE

By Gregory P. Wowchuk, P.Eng.

"YOU CAN NEVER DO MERELY ONE THING."

This maxim, formulated by the late University of California ecology professor Garrett Hardin (1915-2003), is one of the most profound I have encountered during my engineering career. An editorial in *Fortune* magazine at the time (February 1973) said it might be "the most illuminating single sentence authored in the past 10 years."

A HISTORY OF GARRETT HARDIN

Garrett James Hardin was born in Dallas, Texas, and received a BS in zoology from the University of Chicago in 1936 and his PhD in microbiology from Stanford University in 1941. In 1946, he joined the University of California at Santa Barbara, serving as professor of human ecology from 1963 until his retirement in 1978. He was a founding member of the Society for General Systems Research, now known as the International Society for the Systems Sciences.

Hardin authored scholarly papers and gave noted lectures, many of which upset conventional thinking about the very concept of economic growth, globalization and faith in technological progress. Three of his key conclusions were: (1) The human population explosion will damage the environment, deplete natural resources and markedly degrade the quality of human life; (2) Harsh penalties are the result of exceeding carrying capacity; and (3) Individuals will exploit anything that is free to maximize their own advantage. The cost of this exploitation is paid by society as a whole.

Hardin's observations are of particular significance to the engineering profession, upon which society constantly calls to expand the world's "carrying capacity." Hardin's Law serves as a clear warning that we must work harder at anticipating unwanted outcomes. He also emphasized the importance of thinking of systems, not just of the single problem at hand.

Hardin's Law applies just about any time humans devise solutions to problems. It is magnified when applied to more complex systems and when more complex technologies are applied to a problem. It is of particular relevance to the professions, whose members daily apply specialized skills to solve complicated problems. The law is broadly applicable; besides engineering, it is particularly relevant to medicine, economics and government.

SPECIFIC APPLICABILITY TO ENGINEERING

The law of torts, which we studied for our professional practice exam, requires professionals to exercise reasonable diligence and care: "…negligence is of most interest to engineers. Legally, this means failure to take normal care. If people are injured or their property is damaged by another person's carelessness, they can sue the careless person for the amount of the damage. Injured parties must prove that the person sued was not as careful as he or she should have been" (PEO's *Guideline to Professional Practice*, 1998). It is arguably part of "reasonable diligence and care" for an engineer to consider and address unanticipated outcomes of the engineer's work.

Hardin's Law is particularly appropriate to engineering. Engineers very often are called upon and expected to do "one thing." Hardin warns, however, that doing "merely one thing" is improbable. Engineers, therefore, need to weigh alternatives and tradeoffs, and foresee unexpected outcomes.

Roland Schinzinger and Mike Martin, in their book *Introduction to Engineering Ethics* (1999), warn: "So many products of technology present some potential dangers that engineering should be regarded as an inherently risky activity. In order to underscore this fact and help to explore its ethical implications, we suggest that engineering should be viewed as an experimental process. It is not, of course, an experiment conducted solely in a laboratory under controlled conditions. Rather, it is an experiment on a social scale involving human subjects."

Engineers devise human-made systems, often extremely complex ones. Natural systems, thanks to evolution, tend to have greater stability, or at least long, relatively predictable cycles. Extremely complex systems tend to go unstable. One of the issues in chaos theory and complexity theory is the presence of non-linearity. The concept of "tipping point" warns us that, although we might think a system will continue changing only gradually, there can be sudden changes in state. Compounding these facts is that technology tends to increase the speed of propagation of effects. For example, economic disturbances, which used to resolve themselves over a few days, now, in an age of computerized day-trading, can torpedo your stock portfolio in minutes. A paper by Sitabhra Sinha entitled "Are large complex economic systems unstable?" concludes, "economic systems will be more likely to exhibit instabilities as their complexity is increased."

SOME EXAMPLES

Henry Ford, when pursuing his dream of producing automobiles so cheap that almost anyone could afford them, could never have envisioned the impact his idea would have on urban design, accidental death, pollution, and the creation of a "middle" class. Even courting habits were changed by the proliferation of the automobile! Suburbs exploded, necessitating huge investments in infrastructure. Long-established neighbourhoods were cleft apart by multi-lane roadways.

When the Titanic sank in 1912, it became obvious that it had too few lifeboats. An excursion steamer, the Eastland, in response to subsequent legislation, added enough boats for all its passengers. Unfortunately, the extra weight made the Eastland top-heavy and, in 1915, over 800 people were killed when it capsized in the Chicago River.

Microwave ovens didn't only make it possible to quickly heat food; they changed how we eat. Food preparation involving buying meal components, peeling, cutting, boiling and baking gave way to frozen entrées produced on factory assembly lines. Generally, they are much higher in sodium, fat and sugar than what mother used to prepare. One problem was solved, but another was created.

How did Freon (hydrochlorofluorocarbon) become our enemy? Here was a chemical that featured low toxicity, low reactivity and low flammability. It was cheap to manufacture and had excellent refrigerant properties. Unfortunately, it also dissipated widely in the upper atmosphere, ultraviolet light from the sun severed C-Cl bonds, and highly reactive chlorine atoms began chewing at the Earth's protective ozone layer. The process is one of catalysis; it is estimated one chlorine atom can react with 100,000 ozone molecules!

To save electricity costs and bulb replacement, many cities have installed LED traffic lights. One unforeseen problem, however, is that, unlike the incandescent lights they replaced, LED lights don't melt snow that accumulates on them! The electricity savings have been eaten up by labour costs. In St. Paul, Minnesota, crews have to be sent out to blow the lights clean with compressed air. In Green Bay, Wisconsin, workers brush the snow off by hand. Similar problems have been reported for automobile lighting that becomes obscured by snow.

WHAT SHOULD ENGINEERS DO ABOUT IT?

Shortly after the creation of Murphy's Law, air force doctor John Paul Stapp rode a test sled to a stop, surviving 40Gs, and gave a press conference. He said the project's good safety record was due to a firm belief in Murphy's Law and in the necessity to try to circumvent it. In other words, the engineers accepted that undesirable outcomes were probable and consciously worked to foresee and prevent them.

An important quality for any professional approaching a problem is humility. Stop thinking you're so smart. You probably will make mistakes, but your objectives should be to anticipate, learn and address them. Many systems are not as deterministic as you think they are. Most solutions are not as straightforward as you think, either. Here are some suggestions for keeping Hardin at bay:

1. Consider the whole system. While you were asked to solve a single problem, your solution might cause trouble elsewhere in the system, and you may be held accountable. The software code you are writing is not the entire system. The other software modules, the equipment they are in and the people who use the equipment are also part of the system. Hardin specifically warns us against thinking in terms of single-output solutions.

2. Consider the context (social, environmental, economic, etc.) that your solution will operate in. Outcomes that might be acceptable in one context might not be in another. Some degree of ethical and moral judgment should be applied to all projects. The "can do" always should be weighed against the "should do."

3. Try to foresee the unforseeable. It is a professional's duty to warn affected parties about risks. Society relies on our education, experience and judgment. These are part of the "specialized knowledge" for which we have been granted self-regulation. To evaluate areas outside one's competency, others–sometimes even non-engineers–who have that expertise should be consulted.

4. Do "what-if" scenarios. Determine whether more study on possible unexpected outcomes is appropriate. Obviously, actions having potentially more harmful outcomes deserve more scrutiny. Similarly, solutions applied to larger and more complex systems, or those using more complicated technology, will require more comprehensive assessment than those intended for small, simple systems or using simpler technology.

5. Make use of feedback. Monitor system outputs, including ones not necessarily directly connected with the original problem. Early feedback often can rein in and redirect a solution before it causes trouble. Schinzinger and Martin conclude that since engineering is like an experiment in progress, "Monitoring is as essential in engineering as it is in experimentation in general."

Society relies on engineers to solve its problems. Solving problems is what we do. Hardin's Law, however, warns that we must understand that unexpected–and undesirable–outcomes will occur and act preemptively. We must be vigilant, so that the public, which depends on our expertise, is protected from unwanted results. Σ

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