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SCIENTIST AT WORK | HENRY PETROSKI

Engineering a Safer, More Beautiful World, One Failure at a Time

By CORNELIA DEAN

DURHAM, N.C. — For an engineer, Henry Petroski seems strangely enthusiastic about failure.

Not his own, of course. Fear of failure is what sent him, with a bachelor's degree in mechanical engineering, to graduate school rather than to work, and then to a career of teaching and writing, not designing and building.

From his vantage point, failures in design and construction present perfect teaching opportunities. They are object lessons in the history and practice and beauty of engineering. "Failure is central to engineering," he said in an interview. "Every single calculation that an engineer makes is a failure calculation. Successful engineering is all about understanding how things break or fail."

So whether the subject is the building specs in "The Three Little Pigs," the development of the flip-top beverage can or the storage of nuclear waste (a current focus of his), Dr. Petroski thinks and writes in terms of failure. Failure looms even in "The Pencil," his 400-plus-page look at the invention, evolution, crafting and use of the writing implement whose points are so prone to breaking. The book was a surprise best seller.

Dr. Petroski, who is 64, has preached his gospel of failure in books, lectures and articles for publications as diverse as Forbes and American Scientist, where he has a regular column. In the process, he has amassed numerous honors and awards, including membership in the National Academy of Engineering. He has also achieved the status that a reviewer in the journal Science predicted for him after the publication in 1985 of his first book, a catalog of calamity called "To Engineer Is Human."

He is "the meistersinger of the guild."

That first book has on its cover a photo of a famous failure, the collapse of the Tacoma Narrows Bridge, a graceful span across Puget Sound. Its roadway was so narrow and light that it swayed and twisted even in 40-mile an hour winds. It collapsed in 1940, a few months after it opened, in a disaster famously captured on film.

According to Dr. Petroski, the lesson of that bridge is not that it failed, but that it was deemed invulnerable to failure, a judgment that is always a mistake.

Or take Frank Gehry's design for the Walt Disney Concert Hall building in Los Angeles, which Dr.

Petroski describes in his latest book, "Success Through Failure," published this year by Princeton University Press. According to Dr. Petroski, the high gloss of one side of the building reflected so much light at a condo across the street that residents suffered blinding glare and 15-degree temperature increases until the offending wall was resurfaced in a matte finish. This problem is the kind of "latent failure" that emerges only when a design is in use.

And then there is the rolling suitcase Dr. Petroski's wife, Catherine, a writer, bought on a recent trip. She chose it because of its convenient design, he recalls. Only when she used it did she discover it does not roll smoothly when it is full. Moral: a device does not have to fail utterly to be a failure.

In designing and building, engineers calculate how components of their design must perform, and how much stress they can endure before they will give way, an analysis Dr. Petroski says they apply to tasks as varied as driving across a bridge and bending and unbending a paper clip. The paper clip exercise is one he often uses in Introduction to Structural Engineering, one of the classes he teaches at Duke, where he has appointments in both engineering and history.

The analysis of engineering's failures offers some good lessons, Dr. Petroski writes. For example:

¶Success masks failure. The more a thing operates successfully, the more confidence we have in it. So we dismiss little failures — like the repeated loss of a space shuttle's insulating tiles launchings — as trivial annoyances rather than preludes to catastrophe.

¶Systems that require error-free performance are doomed to failure.

¶Computer simulations and other methods of predicting whether components will fail are themselves vulnerable to failure.

¶Devices can be made foolproof, but not damn-fool-proof. This engineering maxim is one of Dr. Petroski's favorites.

¶Today's successful design is tomorrow's failure, in that expectations for technology are continually on the rise.

¶A device designed for one purpose may fail when put to another use. (Is it fair to call that a failure? Dr. Petroski smiled. "Good question," he said.)

In a sense, Dr. Petroski can attribute his career in engineering to a kind of failure, the failure of the United States to beat the Soviet Union into space. Born in Brooklyn in 1942, he was in high school in Queens in 1957 when the Soviet satellite Sputnik became the first artificial moon to orbit the earth, plunging the United States into a science and engineering panic.

Engineers would be hot commodities, his guidance counselor told him. "You were supposed to be able to get a job," he recalled.

So he earned a bachelor's degree in mechanical engineering at Manhattan College, graduating in 1963. But even though he had summer jobs in engineering, including a stint in the pre-computer-era agency that synchronized New York City traffic signals, he worried that he might fail when working on actual devices people would actually rely on. "Engineering is a huge responsibility," he said. "I didn't really feel prepared."

So he enrolled in graduate school at the University of Illinois, where he earned a doctorate in theoretical and applied mechanics in 1968. After a few years of teaching at the University of Texas, he joined Argonne National Laboratory, where he worked on failure — the fracture mechanics of metal components of nuclear reactors.

It was not exactly what Dr. Petroski had studied, but that did not matter a great deal, he said. In the first place, the field was relatively new, so many people were new to it. And secondly, "the whole philosophy of engineering education is to prepare you to do things you had never done" because that's what engineering is — a search for new ways to meet new goals.

At Argonne he discovered one thing about himself and acknowledged something else: he was interested in the policy implications of engineering work and he really loved to write. He started reading more widely on policy issues, and he itched to do more writing, both poetry and prose.

But his schedule at Argonne offered him little free time. "We would go into our offices very early in the morning and break for dinner," he said. So when reactor research began to slow down after the accident at Three Mile Island, he thought about another academic job, one in which he would have time in the summer to write. He accepted an appointment at Duke, and he and his family — his daughter, Karen, is a lawyer, and his son, Stephen, is a mechanical engineer — moved to North Carolina in 1980.

For Dr. Petroski, acceptance of uncertainty and possible failure — he calls it "coping with the imponderable" — is what separates the "given world" of the scientist from the "built world" of the engineer. He took on what might be the ultimate imponderable assignment when he joined the federal government's Nuclear Waste Technical Review Board, a panel of scientists and engineers evaluating the possible use of Yucca Mountain in Nevada as a long-term storage site for nuclear waste.

The scientific analysis of the site, the possible movement of water through it, and so on, is largely complete, he said. Now the engineers must determine what might happen if radioactive waste were stored there — in particular, if it can be stored safely for a million years, the design criterion.

A million-year time frame is a challenge, even an unreasonable challenge, Dr. Petroski said. "But that's what interested me in the problem, a million years. The question is, what kind of society would even be around?"

Knowledge of failure is crucial in considering this kind of problem, Dr. Petroski said. "I basically argue that engineers should arm themselves with all these case histories of failure and reason by analogy."

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But, he said: "I have been told by a good number of engineers that they give my books to young engineers because they do see the value in this message. This is very heartening, because I am getting the validation of the real engineers."

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