SUNDAY FEATURES

Disaster,

the mother of innovation

Lessons learned through failure lead to greater technological advancements, experts say

BY **WILLIAM J. BROAD**
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Smoke billows from controlled burns of oil on the surface of the sea near the site of the BP Deepwater Horizon oil spill in the Gulf of Mexico. PHOTO: BLOOMBERG

Disasters teach more than successes.

While that idea may sound paradoxical, it is widely accepted among engineers. They say grim lessons arise because the reasons for triumph in matters of technology are often arbitrary and invisible, whereas the cause of a particular failure can frequently be uncovered, documented and reworked to make improvements.

Disaster, in short, can become a spur to innovation.

There is no question that the trial-and-error process of building machines and industries has, over the centuries, resulted in the loss of much blood and many thousands of lives. It is not that failure is desirable, or that anyone hopes for or aims for a disaster. But failures, sometimes appalling, are inevitable, and given this fact, engineers say it pays to make good use of them to prevent future mistakes.

The result is that the technological feats that define the modern world are sometimes the result of events that some might wish to forget.

"It's a great source of knowledge — and humbling, too — sometimes that's necessary," said Henry Petroski, a historian of engineering at Duke University and author of *Success Through Failure*, a 2006 book. "Nobody wants failures. But you also don't want to let a good crisis go to waste."

Now, experts say, that kind of analysis will probably improve the complex gear and procedures that companies use to drill for oil in increasingly deep waters. They say the catastrophic failure involving the Deepwater Horizon oil rig in the Gulf of Mexico on April 20 — which took 11 lives and started the worst offshore oil spill in US history — will drive the technological progress.

"The industry knows it can't have that happen again," said David Fowler, a professor at the University of Texas, Austin, who teaches a course on forensic engineering. "It's going to make sure history doesn't repeat itself."

One possible lesson of the disaster is the importance of improving blowout preventers — the devices atop wells that cut off gushing oil in emergencies. The preventer on the runaway well failed. Even before the disaster, the operators of many gulf rigs had switched to more advanced preventers, strengthening this last line of defense.

Of course, an alternative to improving a particular form of technology might be to discard it altogether as too risky or too damaging.

Abandoning offshore drilling is certainly one result that some environmentalists would push for — and not only because of potential disasters like the one in the gulf. They would rather see technologies that pump carbon into the atmosphere, threatening to speed global climate change, go extinct than evolve.

In London on June 22 at the World National Oil Companies Congress, protesters from Greenpeace interrupted an official from BP, the company that dug the runaway well. Planetary responsibility, a protester shouted before being taken away, "means stopping the push for dangerous drilling in deep waters."

The history of technology suggests that such an end is unlikely. Devices fall out of favor, but seldom if ever get abolished by design. The explosion of the Hindenburg showed the dangers of hydrogen as a lifting gas and resulted in new emphasis on helium, which is not flammable, rather than ending the reign of rigid airships.

Engineering, by definition, is a problem-solving profession. Technology analysts say that constructive impulse, and its probable result for deep ocean drilling, is that innovation through failure analysis will make the wells safer, whatever the merits of reducing human reliance on oil. They hold that the BP disaster, like countless others, will ultimately inspire technological advance.

The sinking of the *Titanic*, the meltdown of the Chernobyl reactor in 1986, the collapse of the World Trade Center — all forced engineers to address what came to be seen as deadly flaws.

"Any engineering failure has a lot of lessons," said Gary Halada, a professor at the State University of New York at Stony Brook who teaches a course called *Learning From Disaster*.

Design engineers say that, too frequently, the nature of their profession is to fly blind.

Eric Brown, a British engineer who developed aircraft during World War II and afterward taught at Imperial College London, candidly described the predicament. In a 1967 book, he called structural engineering "the art of molding materials we do not really understand into shapes we cannot really analyze, so as to withstand forces we cannot really assess, in such a way that the public does not really suspect."

Among other things, Brown taught failure analysis.

Petroski, at Duke, writing in *Success Through Failure*, noted the innovative corollary. Failures, he said, "always teach us more than the successes about the design of things. And thus the failures often lead to redesigns — to new, improved things."

One of his favorite examples is the 1940 collapse of the Tacoma Narrows Bridge. The span, at the time the world's third-longest suspension bridge, crossed a strait of Puget Sound near Tacoma, Washington. A few months after its opening, high winds caused the bridge to fail in a roar of twisted metal and shattered concrete. No one died. The only fatality was a black cocker spaniel named Tubby.

Petroski said the basic problem lay in false confidence. Over the decades, engineers had built increasingly long suspension bridges, with each new design more ambitious.

The longest span of the Brooklyn Bridge, which opened to traffic in 1883, was 486m. The George Washington Bridge (1931) more than doubled that distance to 1,100m. And the Golden Gate Bridge (1937) went even farther, stretching its middle span to 1,280m.

"This is where success leads to failure," Petroski said in an interview. "You've got all these things working. We want to make them longer and more slender."

The Tacoma bridge not only possessed a very long central span — 853m — but its concrete roadway consisted of just two lanes and its deck was quite shallow. The wind that day caused the insubstantial thoroughfare to undulate wildly up and down and then disintegrate. (A 16mm movie camera captured the violent collapse.)

Teams of investigators studied the collapse carefully, and designers of suspension bridges took away several lessons. The main one was to make sure the road's weight and girth were sufficient to avoid risky perturbations from high winds.

Petroski said the collapse had a direct impact on the design of the Verrazano-Narrows Bridge, which opened in 1964 to link Brooklyn and Staten Island. Its longest span was 1,299m — making it, at the time, the world's longest suspension bridge and potentially a disaster-in-waiting.

To defuse the threat of high winds, the designers from the start made the roadway quite stiff and added a second deck, even though the volume of traffic was insufficient at first to warrant the lower one. The lower deck remained closed to traffic for five years, opening in 1969.

"Tacoma Narrows changed the way that suspension bridges were built," Petroski said. "Before it happened, bridge designers didn't take the wind seriously."

Another example in learning from disaster centers on an oil drilling rig called Ocean Ranger. In 1982, the rig, the world's largest, capsized and sank off Newfoundland in a fierce winter storm, killing all 84 crew members. The calamity is detailed in a 2001 book, *Inviting Disaster: Lessons From the Edge of Technology*, by James Chiles.

The floating rig, longer than a football field and 15 stories high, had eight hollow legs. At the bottom were giant pontoons that crewmen could fill with seawater or pump dry, raising the rig above the largest storm waves — in theory, at least.

The night the rig capsized, the sea smashed in a glass porthole in the pontoon control room, soaking its electrical panel. Investigators found that the resulting short circuits began a cascade of failures and miscalculations that resulted in the rig's sinking.

The lessons of the tragedy included remembering to shut watertight storm hatches over glass windows, buying all crew members insulated survival suits (about US$450 each at the time) and rethinking aspects of rig architecture.

"It was a terrible design," said Halada of the State University of New York. "But they learned from it."

Increasingly, such tragedies get studied, and not just at Stony Brook. The Stanford University Center for Professional Development offers a graduate certificate in advanced structures and failure analysis. Drexel University offers a master's degree in forensic science with a focus on engineering.

So too, professional engineering has produced a subspecialty that investigates disasters. One of the biggest names in the business is Exponent, a consulting company based in Menlo Park, California. It has a staff of 900 specialists around the globe with training in 90 engineering and scientific fields.

Exponent says its analysts deal with everything from cars and roller coasters to oil rigs and hip replacements. "We analyze failures and accidents," the company says, "to determine their causes and to understand how to prevent them."

Forensic engineers say it is too soon to know what happened with Deepwater Horizon, whose demise flooded the gulf with crude oil. They note that numerous federal agencies are involved in a series of detailed investigations, and that US President Barack Obama has appointed a blue-ribbon commission to make recommendations on how to strengthen federal oversight of oil rigs.

But the engineers hold, seemingly with one voice, that the investigatory findings will eventually improve the art of drilling for oil in deep waters — at least until the next unexpected tragedy, and the next lesson in making the technology safer.

One lesson might be to build blowout preventers with more than one blind shear ram. In an emergency, the massive blades of these devices slice through the drill pipe to cut off the flow of gushing oil. The Deepwater Horizon had just one, while a third of the rigs in the gulf now have two.

Perhaps regulators will decided that rig operators, whatever the cost, should install more blind shear rams on all blowout preventers.

"It's like our personal lives," said Fowler of the University of Texas. "Failure can force us to make hard decisions."