The Challenge of *Challenger*

by Nick D'Alto

IT IS JANUARY 28, 1986. The space shuttle *Challenger* has exploded, killing its entire crew. Among the seven astronauts lost is high school teacher Christa McAuliffe, who would have been America's "first teacher in space."

Imagine being asked to discover the scientific reasons behind this national tragedy. Think of the years of work and high-tech equipment you would need. Richard Feynman used a C-clamp from a hardware store and a glass of ice water to do it. His experiment took less than five minutes.

In his late sixties and in treatment for cancer, Feynman didn't want to serve on the shuttle's accident commission when he got the call. But his wife, Gweneth, persuaded him. "If there's anything there, you'll find it," she said. "There'll be 11 other people, but you'll check the unusual things."

Of the hundreds of possible causes for the explosion, one was the O-ring seals. These were immense rubber washers, 37 feet around but just pencil-thin, which sealed the sections of the shuttle's mighty rocket boosters. If these seals lost their resilience for even milliseconds, they might let a lethal "blowtorch" of gases escape from the rocket's side. Could unexpected cold (it had been just 29 degrees F the morning of the fatal launch) compromise these seals? NASA said, "No."

When Feynman arrived in Washington on February 4, he met his fellow panelists on the commission. Unlike him, they were mostly high military officials and experts in the space industry. They included legendary astronauts Neil Armstrong and Sally Ride, as well as supersonic pilot General Chuck Yeager. While they were all cordial toward one another, Feynman, the theoretical physicist, just didn't seem to fit in the group.

Day after day, the commission listened to long, careful testimony on every aspect of the shuttle program. It was all necessary, but the endless bureaucracy and slow, formal pace frustrated Feynman. Not only that, but after "poking around" behind the scenes, he felt that he was onto something.

Members of a presidential commission investigate the *Challenger* accident at Kennedy Space Center.

On February 10, Feynman made his move. It almost looked as if he were playing a prank. During some of the testimony, a sample of the O-ring seal was being passed around the conference room. When it reached Feynman, he very quietly began taking the exhibit apart. Then he slipped a small clamp out of his jacket pocket, squeezed the rubber strip inside it, and dropped it into a glass of ice water that had been served to him for drinking.

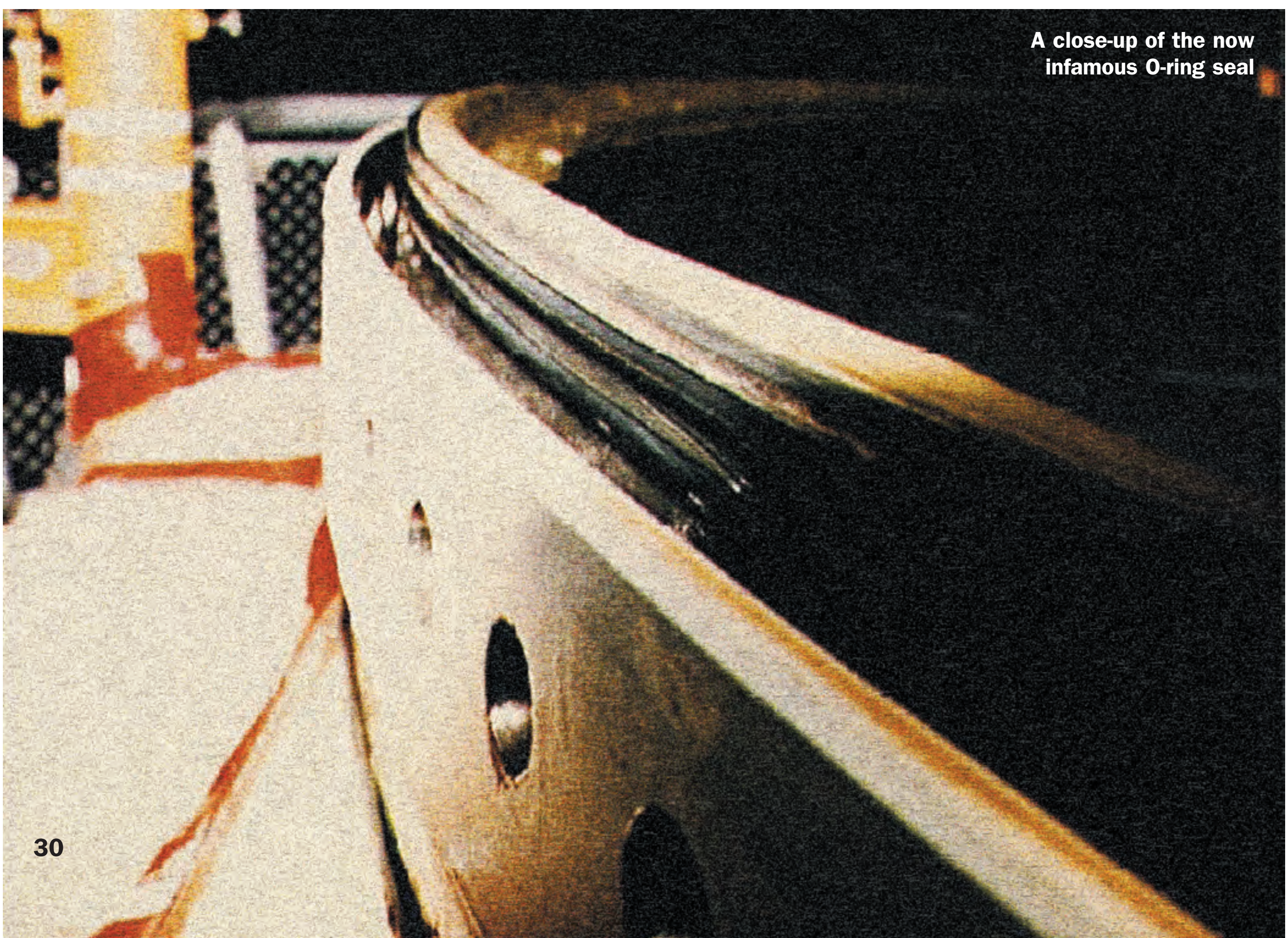
About five minutes later, satisfied with the results of his short experiment, Feynman requested the floor. Then he startled the commission with his results:

"I just took the rubber from the model and [clamped it] in some ice water," he said. "When you undo the clamp, the rubber doesn't spring back. For more than a few seconds, there's no resilience. . .at 32 degrees. I believe this has some significance for our problem."

Feynman's "little experiment" made headlines around the world. Incredibly, he had demonstrated the cause of the greatest tragedy in the history of the U.S. space program up to that point, using an experiment so simple that it could have been performed in any school science lab. In a fitting tribute to lost teacher Christa McAuliffe, Feynman had become a science teacher to the entire world. (To witness his experiment, visit **www.fotuva.org/online/challenger.htm**.)

But how did he know it was the O-rings? Others had thought about it, but he pursued the problem. He even made his own trips to the space facilities, speaking directly with engineers and technicians who worked on the shuttle. It turned out that these frontline workers had voiced concerns about the seals — but no one had listened.

These conversations led to Feynman's second discovery. He began identifying a series of troubling "human factors" — fatal organizational flaws that had allowed the accident to happen. He discovered that management at the agency had been pressuring mission staff to stay on schedule with launches, even though the effects of cold were unknown. Some top decision-makers had even known that the seals might be faulty. But they'd used misleading statistics to convince themselves



A close-up of the now infamous O-ring seal

Feynman's Rules for Good Science

Here are some excerpts from Richard Feynman's report to the *Challenger* commission:

1. If any idea disagrees with the experiment, then that idea *must* be wrong.
2. Perform your science carefully; the easiest person to fool is yourself.
3. To produce any successful technology, reality must always take precedence over public relations. You may fool yourself, but you can never fool nature.

To read his full report, visit **www.ralentz.com/old/space/feynman-report.html**.

that this wasn't a threat. Feynman's conclusion? Faulty technology doomed the shuttle, but ultimately the administrative system was to blame. It had put management ahead of science.

True to Gwen Feynman's prediction, her husband had succeeded on intellect, integrity, a little showmanship, and the courage to do what needed to be done. He even turned out to be the perfect scientist to study the O-rings. Why? While his famous quantum theories seem to defy common sense, the physics of ordinary rubber can prove strange, too.

In Fact, Let's Prove That

We'll substitute a rubber band for Feynman's O-ring. First, stretch the band. Then touch it to your forehead. That's puzzling; the band feels warm. Next, stretch the band quickly 20 times. Even stranger — now it feels cold!

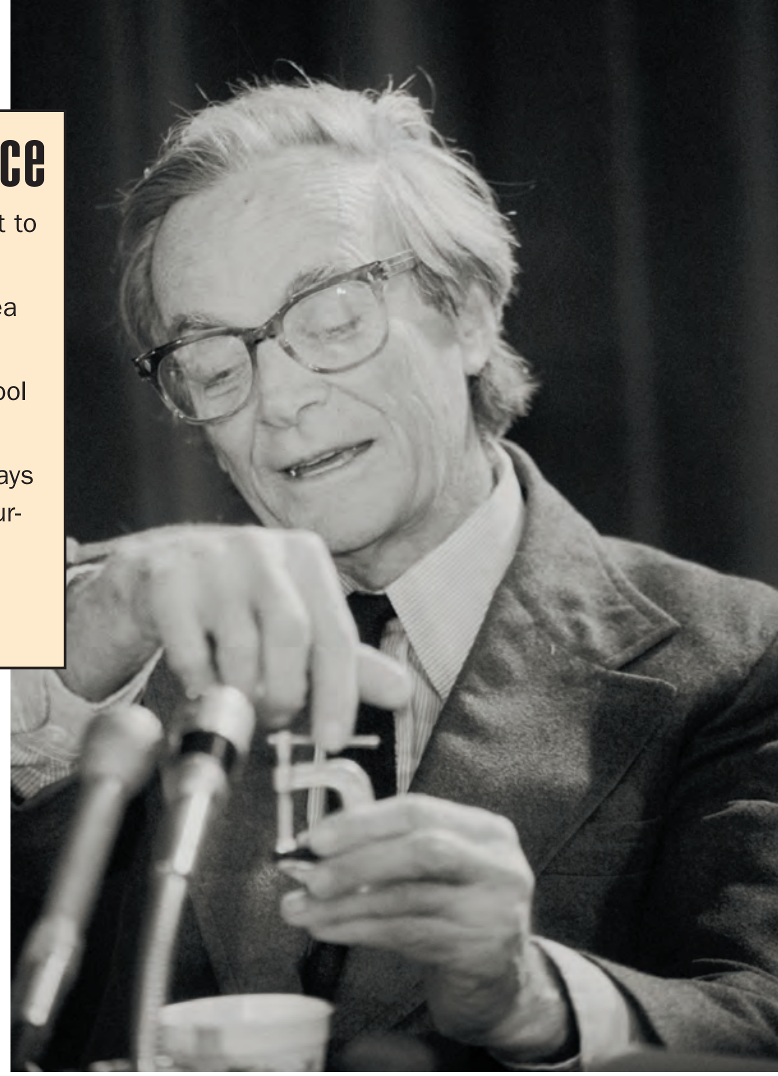
Ready to "stretch the truth" some more? Heat makes a rubber band contract, but cold makes it expand. Virtually every other substance behaves the opposite way. Wow — the physics of rubber seems to be a mess.

That "mess" is really a universal law called *entropy.* Rubber is made from long molecular chains; these start out tangled (high entropy), but straighten out (less entropy) when they're stretched. Add entropy, things heat up. Reduce entropy, things get cold.

The reverse will work, too. Add heat, and rubber molecules tangle up (making a rubber band shorter). But make rubber cold (as on the morning of the shuttle tragedy), and it may lose the entropy it needs to do its job. (Learn more about the physics of O-rings at **www.pspglobal.com/properties-elastomers.html**.)

It turns out that the universe is "getting messier" — or moving toward higher entropy. Physicists call this the Second Law of Thermodynamics. Entropy helps to explain not only the *Challenger* crash, but also the eventual fate of the entire universe. And you just proved it, with a rubber band!

That's Richard Feynman's ultimate science lesson. You can perform the most important science using even the simplest experiments. Just work carefully — and make sure that people listen.



Feynman explains with a simple experiment the solution to a huge problem.

Nick D'Alto is an engineer and writer. On the day the *Challenger* exploded, he was investigating the crash-related failure of an aircraft.