# Caltech professor helps solve Hindenburg disaster

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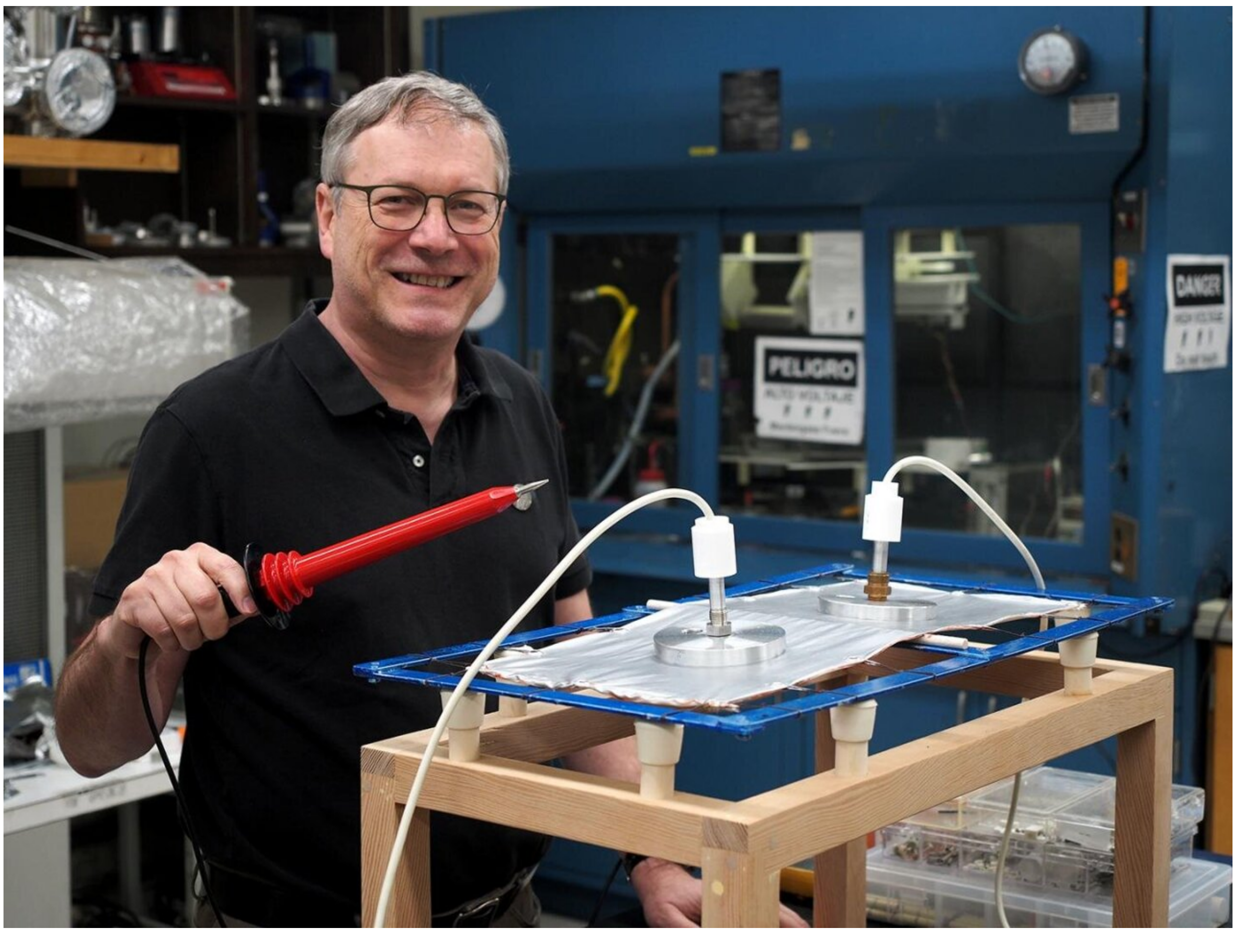


Konstantinos Giapis with the model of the Hindenburg's skin and frame he built. He holds a high-voltage probe in his hand. Credit: Caltech

On the evening of May 6, 1937, the largest aircraft ever built by mankind, a towering example of technological prowess, slipped through the stormy skies of New Jersey and prepared to land. The airship Hindenburg was nearing the end of a three-day voyage across the Atlantic Ocean from Frankfurt, Germany. It was a spectacle and a news event. Onlookers and news crews gathered to watch the 800-foot-long behemoth touch down.

And then, in one horrifying half minute, it was all over. Flames erupted from the airship's skin, fed by the flammable hydrogen gas that kept it aloft, and consumed the entire structure, ending 36 lives.

The ship, already famous before its demise, was seared into the world's memory. The disaster, despite happening nearly a hundred years ago, has remained one of the iconic tragedies of the 20th century, alongside other accidents that captured the public imagination, like the sinking of the Titanic, the Challenger explosion, and the meltdown of the Chernobyl nuclear reactor.

Perhaps one reason why the Hindenburg's final, fiery moments have remained such a source of fascination is the enduring mystery surrounding them. For the past eight decades, people have speculated about how the airship could have been completely devoured by flames in less than a minute.

Now, NOVA, the popular PBS science television show, is taking a new look at the disaster. Its producers tapped Caltech's Konstantinos Giapis, professor of chemical engineering, to help them recreate the ship's last moments and unravel its secrets.

Giapis is not an expert on zeppelins or aircraft crashes, nor is he a forensic scientist. He does, however, have an extensive background studying how electrical charges move on surfaces, and how they can build up to sufficient levels to ionize air and cause sparks. That expertise would prove fortuitous in his search for what caused the disaster, and as it turned out, he would end up exploring many of the same phenomena he studies in his more typical work on transistors and other microelectronic devices.

Still, he was skeptical when approached by the NOVA producers.

"My first reaction was, 'Who cares? This happened 84 years ago. Why would anybody want to find out?'" he says.

But the more he thought about it, the more the problem intrigued him.

"My second reaction was, 'Why isn't the cause known? Why hasn't it been solved in all that time?'"

## Digging up the past

Giapis began looking into historical records of the accident, and soon realized that no one had done experiments to try and find out what had actually happened. Indeed, nearly all the evidence burned up in the blaze. All that existed was a lot of speculation.

What has always been known is that the zeppelin, which was designed by the Zeppelin Company, a German firm known for its large and luxurious airships, contained 7 million cubic feet of flammable hydrogen. Imagine a cigar-shaped balloon as large as a skyscraper filled with explosive gas. Combine that hydrogen with oxygen from the air, and a source of ignition, and you have "literally a bomb," Giapis says.

The key, but long-unanswered, question: How was the fire sparked? Some experts have theorized that the Hindenburg's engines, which burned diesel fuel, were responsible. Others have suggested that the catastrophe was an act of sabotage, meant to make the government of Nazi Germany look bad.

The most credible theories, however, have focused on electrostatic discharge: the same shock you get when you rub your stocking feet on carpet and touch something metallic. Giapis thought this was most likely. The basic idea is that as the Hindenburg moved in the stormy atmosphere, its skin built up a static charge. And just like the jolt your finger gets when you reach for a doorknob, the Hindenburg might have been zapped when it came in for its landing in New Jersey. If the ship's hydrogen had been leaking, as it is believed, that zap could have set the gas afire.

There were holes in that theory though. First, the zeppelin did not catch fire the moment it dropped its mooring ropes to the ground, as would be expected if the ropes completed the circuit necessary to create a spark. Second, the chances of a single spark happening in the very same spot on the Hindenburg where the hydrogen was leaking seemed too slim to be likely.

To get to the bottom of the mystery, Giapis would have to resolve both of these issues.

## 'Modeling' the problem

Now fully onboard with the project, Giapis first built a model of a portion of the zeppelin's outer surface in his laboratory on the Caltech campus. This setup consisted of a cotton cloth similar to the original, stretched with natural-fiber strings over an aluminum alloy scaffold and impregnated with multiple layers of Cellon dope, which is a paint containing a polymer, chemical binders, and aluminum flakes. This turned out to be more complex than Giapis first expected because some of the details of the zeppelin's construction have been lost to time and others were trade secrets closely guarded by the Zeppelin Company.

"I found some historical records of what was in those layers, but the precise composition was kept secret," he says. "I analyzed old samples of the skin using modern techniques to get clues. In the end, I had to create multiple versions of this coating for the fabric and evaluate their electrical properties."

The skin was lashed to the aircraft's aluminum frame, but kept from touching it by wooden pegs inserted between the two. The gap between the frame and the skin would prove fatal to 35 of the 97 individuals onboard the airship plus one ground-crew member.

Witnesses at the scene claimed to have seen a glowing aura on parts of the ship. The American and German investigation committees concluded this charge meant the airship was charged to a high voltage, but disagreed on the exact mechanism of how that caused the disaster.

The American committee theorized that the hydrogen was ignited by a phenomenon known as corona discharge, or St. Elmo's fire; this "soft" leakage of high voltage charge from a surface sometimes occurs on the masts of ships at sea, or on airplane surfaces in flight during stormy weather. In contrast, the German investigation committee suggested that a high-intensity spark had instead triggered the explosion.

Giapis did not believe that the American theory could explain the ignition.

"This diffuse glow occurs outside the airship and its energy is very low," he says. "It generally is not sufficient to ignite hydrogen." Thinking the German theory was more plausible, he set out to test it in his lab.

As the NOVA crew filmed, Giapis charged his model of the skin to an electrical voltage consistent with atmospheric charging in stormy conditions at the airship's elevation. Then he grounded the scaffold frame he had built.

Nothing happened.

Then he sprayed a mist of water to the skin, simulating the light rain that was falling that spring evening in New Jersey. Within moments, loud and powerful sparks jumped across the gap from the skin to the frame, just as the German committee had proposed.

## An unexpected result

Next, Giapis needed to determine why there was a four-minute delay between when the Hindenburg was moored to the ground and when it caught fire. The members of the German investigation committee proposed that the delay could be explained by the light rain. Their theory was that the ropes only began conducting electricity after they got wet, and so the frame only became grounded once the ropes had become sufficiently moist.

In his lab, Giapis suspended a section of large rope very similar to the mooring ropes used on the Hindenburg and applied a high voltage to it.

To his surprise, the rope was conductive even while dry. It was previously thought that electricity would not flow through dry rope, that it was an insulator.

"The Germans said the rope became conductive after four minutes in the rain, but my experiment showed that the rope was conductive enough to ground the frame the moment it was dropped. And that meant the theory fell apart, because the spark should have occurred much sooner. By my estimates, it takes 10-15 seconds to ground the frame with a dry rope, not four minutes."

Giapis agonized over how to explain that discrepancy. Because of delays due to COVID-19 shutdowns, he was not able to run the rope conductivity test until just a few days before the shoot. "We were about to start filming and my theory had a gaping hole in it. I had to think hard and fast." And then, just two days before the shoot, the answer came to him: After the ship was grounded, it became more electrically charged.

Before the mooring ropes made connection with the ground, the Hindenburg collected a positive charge. However, this continued only to a point; indeed, as the skin became more positively charged, it also more strongly repelled any additional charge from collecting.

Then, when the mooring ropes were dropped, electrons from Earth's surface moved up to the frame, giving the ship a positively charged skin and a negatively charged frame.

Just like how the north end of a bar magnet will be attracted to the south end of another bar magnet, that negatively charged frame began pulling more positive charge out of the stormy atmosphere and onto the ship's skin. In other words, by grounding the frame with the mooring ropes, the landing crew had inadvertently made more "room" for positive charge to gather on the ship, setting the stage for the disaster.

"When you ground the frame, you form a capacitor—one of the simplest electric devices for storing electricity—and that means you can accumulate more charge from the outside," Giapis says. "I did some calculations and I found that it would take four minutes to charge a capacitor of this size!"

With the ship now acting as a giant capacitor, it could store enough electrical energy to produce the powerful sparks required for igniting the hydrogen gas—which, based on eyewitness accounts, may have been leaking from the rear of the ship near its tail.

This theory could also help explain a question that puzzled Giapis from the start: How did a spark occur in just the right spot to ignite leaking hydrogen?

"Hydrogen was leaking at one specific location in this humongous thing. If there is a spark somewhere else on the ship, there is no way you would ignite a leak hundreds of feet away. Charge could move on wet skin over short distances but doing that from the front of the airship all the way to the back is more difficult," he says. "So how did the spark find this leak?"

Any place where a part of the frame was in close proximity to the skin would have formed a capacitor, and there were hundreds of these places all over the ship, Giapis says.

"That means the giant capacitor was actually composed of multiple smaller capacitors, each capable of creating its own spark. So I believe there were multiple sparks happening all over the ship, including where the leak was," he says.

## Science, but make it entertainment

Science in an academic setting tends to follow a pretty standard formula: Identify a topic to study, find funding, conduct the research, write a paper on the findings, and get published in a peer-review journal.

Doing experiments for a popular-science television show is very different from that, but in some ways, there are similarities, too, Giapis says.

"This is entertainment, but from my perspective, it's a scientific experiment, and I wanted to get the numbers right and get the story right," he says.

What he did not realize at first when he agreed to work with NOVA was that the show has its own form of peer review. For this episode, NOVA's producers asked Andy Ingersoll, professor of planetary science at Caltech and a member of the science teams of several NASA research missions, including Voyager and Cassini, to review Giapis's work.

"It's a nice little physics problem, and it was a pleasure to have Kostas explain it to me," Ingersoll says.

And Giapis said he enjoyed working on it.

"This was a very interesting story. It requires experimentation. It requires thinking. It requires some forensics, explaining the timeline of events," he says.

And now he says he understands why people are still so fascinated by the Hindenburg, nearly 100 years after its final, fateful voyage.

"What an apparition it must have been to see. People were mesmerized by it," he says. "It was one of the wonders of the world and the best of its day. It was an unbelievable mode of transportation, a flying hotel for the richest of the rich. And it was the first televised major air disaster that people watched all around the world."

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