MASTERING THE PHYSICS OF DISASTER

The recent US Air crash in Pennsylvania is taking a lot of Robert Kadlec's time these days. Kadlec is in charge of aviation-accident investigations for Failure Analysis Associates, an engineering consulting firm headquartered in Menlo Park, California, that specializes in determining how man-made structures and systems fail and in finding ways to prevent such failures. The company has been retained to look into the cause of the US Air disaster on 8 September.

Kadlec remembers well working on his first aircraft case, 20 years ago. A professor of aerospace engineering sciences at the University of Colorado at the time, he received a phone call from longtime acquaintance Bernard Ross, one of the founders of Failure Analysis.

"Ross wanted me to help them with an aviation crash that had just occurred in the part of Oregon northwest of Portland where the Columbia River takes a turn northward before heading finally to the sea. The question was, Had the plane lost power or had the pilot been at fault? I flew to Portland and marched off into the forest with the team sent to find the downed plane and bring back any evidence that would shed light on the cause of the accident. Once at the crash site, it was easy to locate the propeller—it had slashed through a 16-inch-diameter Douglas fir. With this information, we made a mock-up of the accident back in the laboratory and were able to demonstrate that in fact the plane was under full power at the time of the crash."

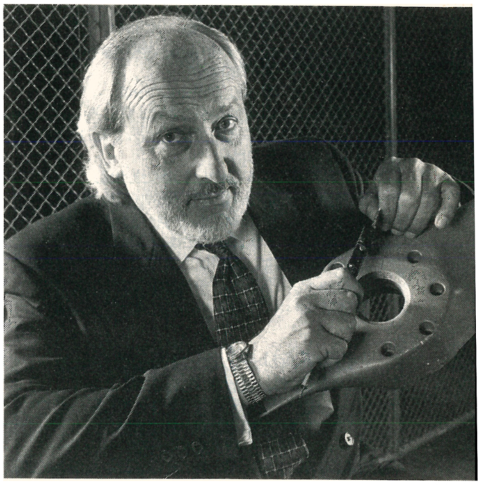
Although Kadlec continued working as a university professor for several more years, his appetite for such investigatory work was sufficiently whetted that he opened a one-person Denver office for the company. "I had clients and worked on several cases," he recalls. "During this period, my interest in the analysis and reconstruction of accidents and other failures blossomed naturally until it became the most interesting thing I was doing." He joined Failure Analysis full-time in November 1978 and in 1982 became a corporate vice president and head of the firm's Los Angeles office. Kadlec directs several of the company's regional offices and is principal director of investigations for aviation accidents, fires and explosions.

Failure Analysis is an archetype of the small startup company that has made it big. It was founded in 1967 by three metallurgy professors from Stanford University and two others from the old Stanford Research Institute (now SRI International). "They had been receiving calls from people asking for help in finding out why a metal part broke or a structure failed," says Kadlec. "So they each invested a small amount, enough to pay a secretary and set up an office." Now the company has ten offices in the US and Canada, three in Europe and one in Asia, and it employs some 400 persons, about half of whom are scientific and technical professionals. Initially known for its investigations of disasters resulting from metallurgical and structural failures, the company has steadily broadened its business to include risk assessment, biomechanics, human factors and consulting on environmental matters ranging from indoor air pollution to contaminants in the air, water or soil.

Sorting out what happened

The common thread in all of the company's activities is isolating the several individual problems that are nested within the event under investigation. "What we do is try to see through the cloud of incomplete information in an effort to sort out what happened, why it happened and how it could be prevented," explains Kadlec.

The US Air crash near Pittsburgh provides an example. Scientists, engineers and technicians with expertise in materials, mechanical and aeronautical engineering, combustion and fluid mechanics, computer animation and human behavior visited the accident scene to map the wreckage, examine the damage, search for materials defects and collect physical evidence. In the laboratory, components that have been collected are being compared with blueprints and specifications; parts are



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being subjected to stress, fatigue and fracture tests; and voice and flight data from the flight recorder (the so-called black box) are being analyzed. The team is also examining statistical data from similar accidents or those involving the same type of equipment, studying weather patterns, investigating combustion processes and determining the behavior of the flight crew, all in an attempt to construct a theory of what might have happened. This "failure sequence hypothesis" can then be verified by subjecting components and systems to instrumented tests, constructing scale-model mock-ups of the accident and creating computer models of the events. Computer animation of a crash often plays a key role in visualizing what happened and in communicating the results of the analysis to outsiders and nonexperts.

In fact, communicating their findings constitutes a major part of what Kadlec and his Failure Analysis colleagues do. The company's clients often are or expect to become targets of litigation resulting from failures or accidents involving their products, equipment or property. Failures can be large or small: Kadlec has worked on cases ranging from exploding champagne bottles to the Exxon Valdez oil-tanker spill in the Gulf of Alaska. The most valuable service to the client is therefore a clear and understandable explanation of what happened and why, an explanation that is convincing to the parties in the litigation, including the jury if the case proceeds to trial.

One such case was the high-profile litigation following the 1986 New Year's Eve fire in the Du Pont Plaza Hotel in San Juan, Puerto Rico. It was initially alleged that the 97 people killed in the disaster were felled by smoke and toxic fumes from the fire, which was set by an arsonist. But fire dynamics modeling by Failure Analysis showed how the fire spread and indicated that in fact the fatalities were due to a rapidly moving flame front traceable to poor fire-protection measures.

Owing to the large number of parties involved, each with its own legal team, the Federal Court rented a high-rise in San Juan and turned the entire first floor into a courtroom. "As you can imagine," says Kadlec, "the atmosphere was tense and adversarial. I was on the witness stand for a week explaining our results. Cross-examinations, designed to undermine your credibility, were challenging. But my testimony was instrumental in convincing the jury to find for my clients, who were manufacturers of hotel products."

Childhood interests

In a way, Kadlec began preparing for his Failure Analysis career as a child. He was raised in a rural area about 40 miles from Chicago, where his father had a contracting business. So, Kadlec notes, "I've been building things since I was a kid." Things really began to click in high school when his physics teacher, E. M. Curtis—"we called him EMC-squared"—took a special interest in Kadlec and encouraged him to continue his education. College had to wait a year, however, while Kadlec earned the money needed for school by working in his uncle's sheet-metal shop, sharpening his three-dimensional geometry skills in the process. He entered the University of Minnesota in 1961.

Based on his experiences working for his father and uncle, Kadlec initially enrolled in civil engineering. However, the early 1960s was an exciting time for aeronautical engineering, especially with the progress in manned spaceflight, and Kadlec soon switched fields. He also retained an enthusiasm for physics and so spiced his engineering curriculum with numerous physics courses. "I tried to maintain a balance between engineering and physics, and I never left physics that far behind," says Kadlec.

During this period another teacher encouraged Kadlec to apply for a summer internship at NASA's Manned Space Flight Center in Houston. The atmosphere there was exhilarating, as a mix of scientists and engineers engaged in the exciting work of preparing for the Apollo missions to the Moon. "After working two summers in Houston, I knew I wanted to get more; I knew I was going to go to grad school." So in 1965 Kadlec enrolled in aeronautics and astronautics at Stanford University.

"The department was a very dynamic place, with lots of people doing work that touched on the boundaries of physics, such as high-temperature gas dynamics," recalls Kadlec. "In fact, my professor insisted that I also qualify for a minor in physics. This entailed passing the same qualifying exam required of predoctoral physics students, a closed-book ordeal spanning two weekends and covering all areas of physics."

His thesis adviser was Sotos Koutsoyannis, who became a guiding light and close friend. Koutsoyannis enticed Kadlec to study the use of laser spectroscopy for measuring nonequilibrium distributions in an excited gas (neon discharge) by means of Doppler-broadened line shapes. Upon completing his degree in 1972, Kadlec immediately joined the University of Colorado as an assistant professor of aerospace engineering sciences.

Kadlec made his first contact with Failure Analysis even before leaving California. Another childhood interest brought that about. "As a kid I loved ice hockey, and one of my dreams was to play professionally," Kadlec says. "As an undergraduate at Minnesota, I played hockey all four years. Surprisingly, after I got to California, I kept meeting ex-hockey players." One of the players was Bernard Ross, who also happened to be an alumnus of Kadlec's department at Stanford. "As we got to know one another, he began talking about his new company and invited me to work part-time. I remember driving up to the empty parking lot at Candlestick Park to be part of a test involving spare tires from tractor–trailer rigs. I was fascinated."

Although it's been 16 years since Kadlec left academic life, he says he still thinks of himself as a teacher: "I am really proud of my work, which combines so many elements of physics and education. Only now my classes are held in client meetings and in the courtroom."

—ARTHUR L. ROBINSON ■