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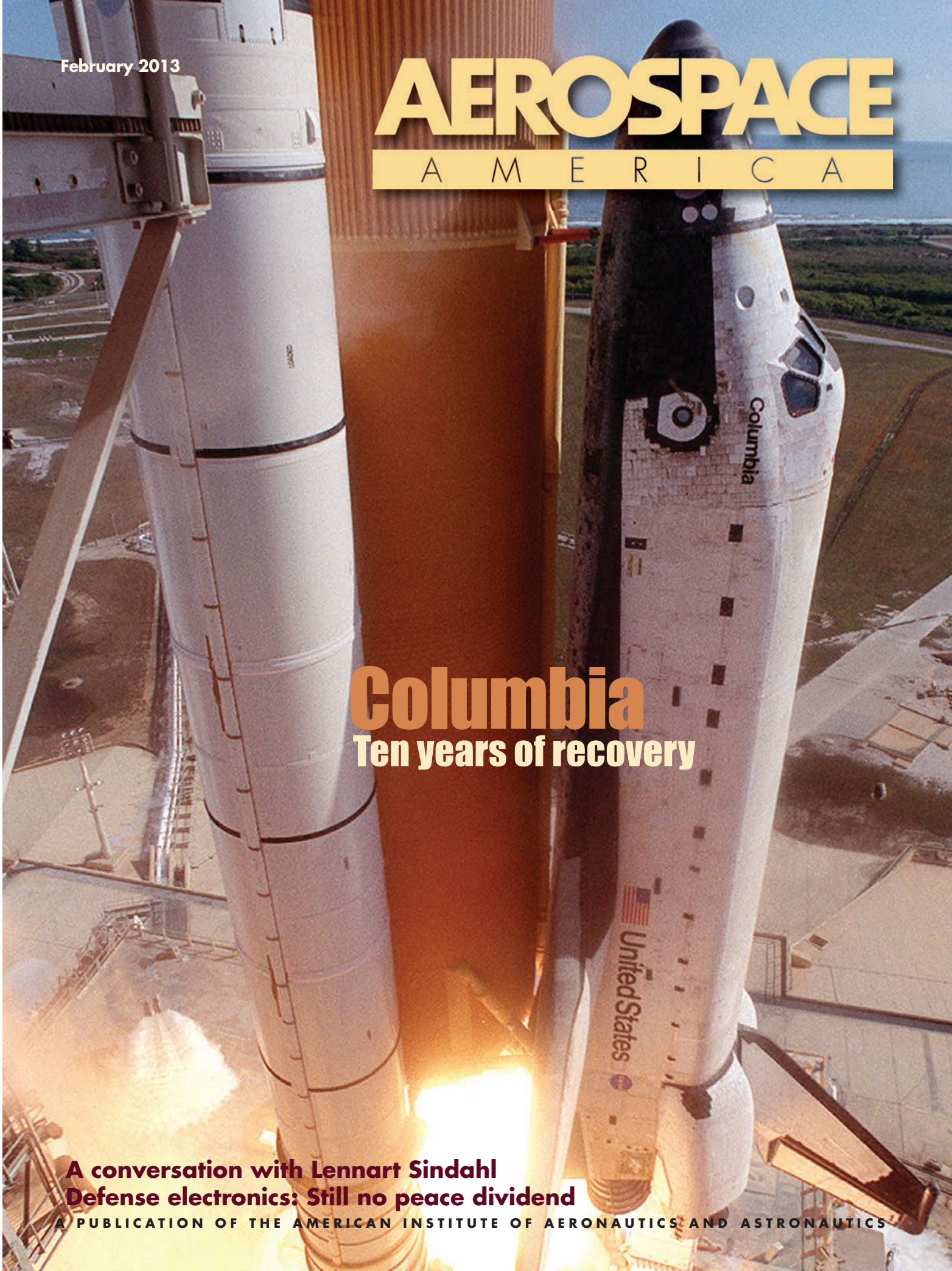
# AEROSPACE AMERICA




## Columbia
### Ten years of recovery

**A conversation with Lennart Sindahl**

**Defense electronics: Still no peace dividend**

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*Although a decade has passed since the tragic loss of the space shuttle Columbia and her crew, the recovery effort has not ended. Fragments of the orbiter continue to be found and returned to NASA, whose experts painstakingly catalogue and study them to learn as much as possible from the accident and pass along its sobering lessons to those who design and build vehicles for spacefarers of the future.*

*Contact with Columbia is lost. Credit: NASA.*


**by Leonard David**
Contributing writer

**It has been 10 years** since the Columbia shuttle orbiter and its seven-person crew ended their journey in catastrophe. On February 1, 2003, after a nearly 16-day flight, tragedy struck as the spacecraft faced fierce heat on reentering Earth's atmosphere. Columbia broke apart and fell across a 120-mile swath of East Texas and western Louisiana.

A detailed, soul-searching investigation into the accident found that the physical cause was damage by a piece of insulating foam that separated from the left 'bipod ramp' (which connected the shuttle to the external tank), striking Columbia's left wing 81.9 seconds after launch. That foam strike made a hole in a reinforced carbon-carbon (RCC) panel on the wing's leading edge, allowing a torrent of superheated air to sweep inside the internal wing structure during reentry. This led to the structural failure of the wing, destruction of the orbiter, and loss of the crew.

"I'm sure that Columbia, which had traveled millions of


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miles and made that fiery reentry 27 times before, struggled mightily in those last moments to bring her crew home safely once again. She wasn't successful…," said Robert Crippen at the astronauts' memorial service. Crippen, along with John Young, had flown the orbiter on its maiden voyage in April 1981.

Now, a decade after that terrible day, the recovered and inspected components of the ill-fated orbiter remain as powerful and timeless messages bearing witness to technical errors, lack of effective communication, and a broken safety culture.

### Solemn resting place

Michael Ciannilli is the project manager for the Columbia Research and Preservation (CR&P) Office at the Kennedy Space Center in Florida.

The CR&P Office is a nearly 7,000-ft$^2$ room located on the 16th floor of the 'A' Tower at KSC's Vehicle Assembly Building. A visitor to the site cannot help being overwhelmed by emotion when scanning the recovered wreckage at the center, a solemn resting place for over 80,000 large and small pieces. In total, about 80,000 lb of Columbia have been retrieved.

"We have 40% of the vehicle in," Ciannilli tells *Aerospace America*, "and we know some things will never be recovered. But we do continue to recover items, and have steadily done so since the accident."

Because of this, he says he "is of the strong opinion that we still have pieces out there." Indeed, a piece of debris from Columbia was discovered eight years after the 2003 disaster. The object—a round aluminum power reactant storage and distribution tank—was found in July 2011 in Texas. The tank, 40 in. in diameter, was discovered in an exposed area of Lake Nacogdoches, about 160 mi. northeast of Houston. Lower lake water levels resulting from local drought conditions led to exposure of the hardware. The piece was one of 18 tanks on the shuttle that stored supercold liquid oxygen and liquid hydrogen.

Ciannilli says finding Columbia elements becomes more difficult with time because of changing conditions. Still, hikers may find pieces, as might hunters in the woods. Various construction projects could unearth orbiter parts as well. "I would estimate that about 95% of the calls we get turn out not to be Columbia. But we appreciate the calls. Some of the items are really hard for us to identify…and it takes extra meth-

*Columbia's main engine power head was recovered from Fort Polk in Louisiana. Credit: NASA/CAIB.*


*Columbia Accident Investigation Board members and a FEMA official survey shuttle debris near Nacogdoches, Texas. Credit: Mark Wolfe/FEMA.*

ods to go into a laboratory and find out. I'd rather err on the side of caution," he adds.

Even though NASA and its contractors are no longer in the field searching, the agency maintains a telephone hotline and e-mail address that the public may use for reporting information that might help recover as much of Columbia as possible and aid others studying the mishap.

## Reconstruction database

The vast majority of people who find Columbia components do the right thing by contacting NASA, Ciannilli emphasizes. But for those itching to cash in on debris (by use of eBay, for example), personally retaining or selling such an item is against federal law. All the material is U.S. government property; unauthorized persons in possession of accident material will be prosecuted. "We don't want anybody getting in trouble or having any issues. We are happy to facilitate getting items back to us," he points out.

Typically, a call comes into the CR&P Office and starts the process for ascertaining that a Columbia component has been found. That narrowing down is partly determined by whether the item was discovered in the orbiter's return-to-Earth flight path. A photo of the component, with something showing the scale of the piece, is very useful, says Ciannilli.

The CR&P Office uses an expensive database developed during the 2003 recovery effort for use by the Columbia Reconstruction Team in the Kennedy Shuttle Landing Facility Hangar. Called the CRDS (Columbia Reconstruction Database System), it includes the recovery location, latitude/longitude, images, and engineering descriptions of all Columbia debris received from February 2003 to the present.

Funded by NASA Kennedy, the CR&P Office seeks to simplify research and location of debris items, prevent further damage to the debris, make the database as accurate and comprehensive as possible, and receive, evaluate, document, inventory, store, ship, and track all Columbia hardware, whether located at KSC or elsewhere.

## Painstaking search

Recovered elements of the craft range from dime-sized or smaller to weighing a few thousand pounds. "I personally attribute a lot of success in recovery of Columbia to

*During search operations, this view of a KSC hangar shows a portion of the recovered pieces of Columbia debris. Credit: NASA Kennedy.*

the volunteers. We had over 16,500 people join forces" to search for the vehicle, says Ciannilli.

Early in the process, NASA and the FAA partnered to assess the latter agency's radar data "to get an idea of where things were located," he says.

Soon after the orbiter's catastrophic breakup, a painstaking examination of the main 2,400-mi.$^2$ search corridor began. The combined efforts of five organizations—NASA, the Federal Emergency Management Agency , the EPA, and the U.S. and Texas Forest Services—made the search possible. Individuals from these agencies, aided by local authorities and landowners, worked long hours under arduous conditions over difficult terrain to recover debris. Extensive ground and air searches were carried out to scour a 10x240-mi. corridor along the projected shuttle reentry flight path.

Early in the recovery effort, teams from NASA, the FBI, the National Guard, urban search and rescue organizations, the Dept. of Public Safety, and others conducted a successful search in East Texas to recover and bring home Columbia's crew.

A FEMA Disaster Field Office based in Lufkin, Texas, was established as headquarters for the Columbia recovery operation. Over 100 federal, state, and local agencies, as well as volunteer groups, came together for the effort, deemed a model of cooperation that also set a high standard for future Dept. of Homeland Security cooperative endeavors.

The priorities of the participating agencies were threefold: Ensure public safety, retrieve evidence—pieces of the shuttle that could ultimately determine the cause of the tragedy—and reimburse the expenses of state and local governments and of private citizens who may have sustained property damage from the accident or search.

Guidelines prepared by the state of Texas, NASA, and the EPA enabled the teams to collect, document, tag, and transport nonhazardous debris without prior EPA or NASA clearance.

Among NASA's tasks was the rapid identification of orbiter-related hazardous materials, such as tanks containing toxic substances, or unexploded pyrotechnic devices. Once such objects were found, the EPA secured and removed them immediately. Working with local authorities, EPA also quickly cleared nearby school campuses and public access areas. In addition, it tested air and water samples taken along the flight path for shuttle contaminates. It found no evidence of hazardous material in the atmosphere or drinking water supplies.

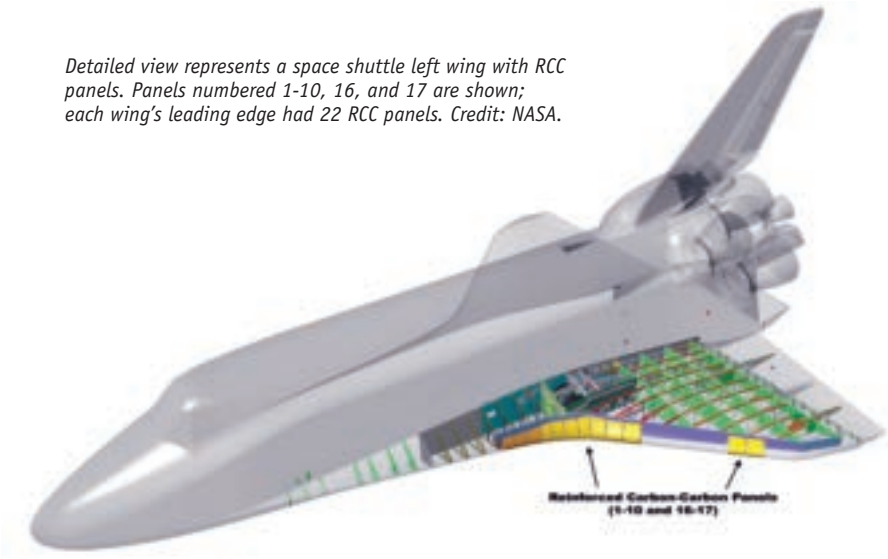
*A round 40-in. aluminum storage tank from space shuttle Columbia's power reactant and storage distribution system was found in 2011, resting on the edge of Lake Nacogdoches in Texas. Lower lake water levels resulting from local drought conditions led to exposure of the hardware. Credit: NASA/Nacogdoches Police Dept.*

## Matriarch of the fleet

Ciannilli notes that recovered Columbia debris is available for study by researchers and the educational community. Scientific, academic, and governmental organizations that are interested, he says, are asked to submit their requests. Lehigh University, for example, used some components to conduct material/failure analysis for graduate students. Other groups have studied recovered items to delve into certification issues for spacecraft, or to reconstruct the physics that acted on the orbiter materials during and after reentry.

"Columbia was the oldest vehicle…the matriarch of the fleet," Ciannilli notes. "She had a great number of flights on her—28 missions—and experienced a lot of flight time and aging time." More pieces of Columbia will likely be borrowed for testing and used to aid understanding of the rigors of spaceflight and the reentry process, to

*One of the larger pieces of recovered debris is Columbia's nose gear, shown here with tires still intact. Credit: NASA/CAIB.*

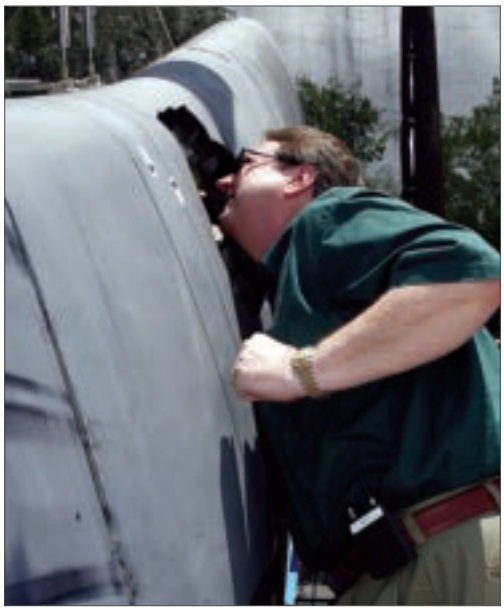



*Detailed view represents a space shuttle left wing with RCC panels. Panels numbered 1-10, 16, and 17 are shown; each wing's leading edge had 22 RCC panels. Credit: NASA.*

help shape a foundation for future spacecraft, and to educate new generations of those who will build them.

The doors of the CR&P Office are open for commercial firms engaged in supplying crew vehicles for NASA's use, he says. "It's an important sharing of information. When it comes to commercial crew, those folks are just starting to get their feet wet…just starting their design and early test phase of vehicles. There are a lot of lessons learned that can come from the government space shuttle program to commercial ventures."

Wayne Hale, a former NASA shuttle program manager, holds a similar view. "The Columbia accident offers, among other things, a set of technical lessons. How do structures fail? What kinds of stresses did that vehicle undergo…and therefore, how can we build better, safer spacecraft and aircraft in the future?"



*CAIB member Scott Hubbard inspects the damaged RCC panel 8 following a test. Credit: NASA/CAIB.*

For commercial groups, visiting the CR&P Office and viewing the collection of Columbia components also is a good idea, Hale tells *Aerospace America*. "It would be a good place for their management and leadership to go and hear the story. Also, keeping it there and allowing researchers access to Columbia as they get better and better research techniques…will pay off in the long run," he believes.

An earlier exhibit on Columbia also should be taken around for viewing by the NASA workforce, adds Hale. Similarly, having those who build commercial spacecraft go and visit the Columbia research office will reinforce the lesson that "bad things can happen if you don't pay close attention to details."

### A design that invited disaster

Space policy expert John Logsdon, George Washington University professor emeritus, was a member of the Columbia Accident Investigation Board (CAIB). Among the board's duties was to ascertain the facts and determine the actual or probable causes of the mishap (both the dominant and contributing root causes), present important observations, and recommend actions aimed at preventing future accidents.

Logsdon became a CAIB member about a month after it was formed. His first experience as an official of the board, he recalls, was seeing the recovered debris, at that time sprawled out in a KSC hangar. The sight made an indelible impression. "You got a sense of the forces that had torn this vehicle apart. You had small pieces and big pieces; you saw the nose wheel intact."

Brought on to the CAIB for his space policy and space history expertise, Logsdon did not have the specific role of analyzing Columbia's fragments. "But those who did said that the debris told them the story… that the problem was on the left wing, and that there were vivid differences in the character of the remaining pieces that had been recovered," he notes. "As the forensic people say, 'something bad happened around here.'"

Concerning the lingering lessons of what Columbia's recovered debris can teach the commercial spaceflight community, Logsdon says he is not sure they need reminding about the risks of space. "Let's make sure the people who are building new systems recognize that something like this *can* happen," he emphasizes.

Logsdon observes that some Apollo as-

tronauts, as well as others, have opposed the idea of commercial crew, seeing NASA as having unique expertise in how to accomplish human spaceflight. "And yet our [CAIB] findings were that NASA didn't do its job. So the idea that NASA can do this [human spaceflight] and the private sector cannot seems to me to fall down when one examines the indictment of NASA's performance in the Columbia board report….That idea doesn't square with the evidence."

Looking back on Columbia and the overall design of the space shuttle system, Logsdon says: "In retrospect, those design decisions look a little unfortunate." For example, vulnerable parts of the orbiter were put below, particularly the external tank, with the design requirement that things would not come off. But they did, from day one. This was "a design that invited disaster at a certain level," he says.

*A reconstruction team member examines debris with a video-microscope, searching for clues to the events that led to Columbia's breakup. Credit: NASA/CAIB.*

### Physical cause statement

Another CAIB member was Scott Hubbard, then director of NASA Ames. He is now professor of aeronautics and astronautics at Stanford University.

"It was the part count. The things that were recovered showed a lot more material from the right side of the orbiter than the left. The reconstruction of Columbia was all laid out like a crime scene grid. The distribution of what was recovered and what wasn't…that was another indicator that what happened was near panel 8 on the left wing. That was informative," Hubbard tells *Aerospace America*.

Quite literally, a 'telling piece' of evidence came from the recovered OEX (orbiter experiment support system) recorder, found buried in a slope by a firefighter in a previously searched area near Hemphill, Texas, some six weeks after the accident. From the OEX tape NASA was able to recover data recorded within two seconds of the actual destruction of Columbia. As a result of this find, experts retrieved 15 seconds of data not available anywhere else—information critical for the effort to resolve the root cause of the accident.

"The recorder showed us all the things that went off line when it happened. It began to give us a time line of what events occurred. All of that was extremely valuable as a piece of the total story at the time," Hubbard says.

But the true smoking gun came via computational modeling, reinforced by experimental testing with a large compressed-gas gun. At Southwest Research Institute in San Antonio, Texas, Hubbard oversaw tests

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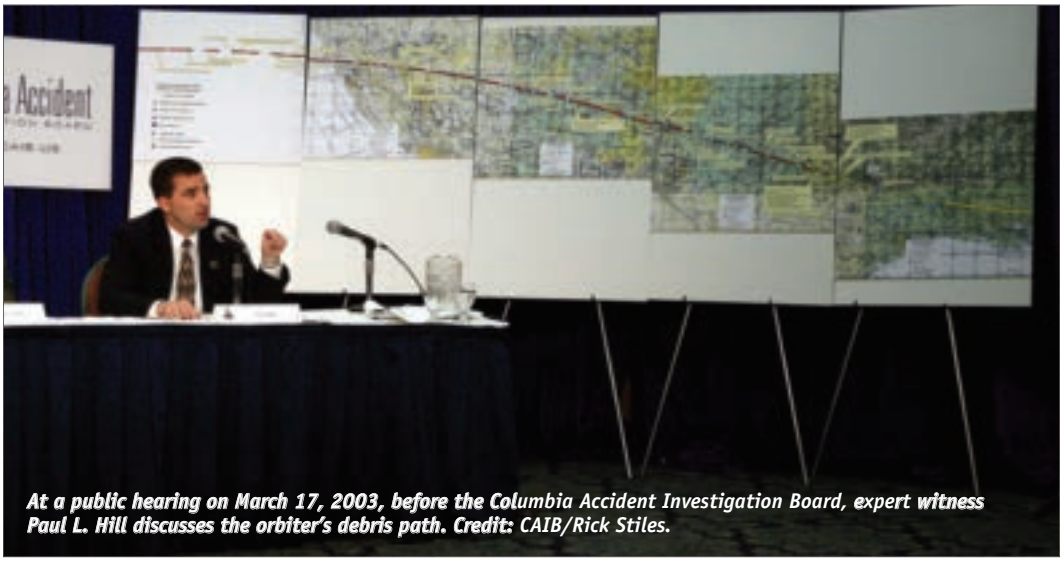


***At a public hearing on March 17, 2003, before the Columbia Accident Investigation Board, expert witness Paul L. Hill discusses the orbiter's debris path. Credit: CAIB/Rick Stiles.***

*(Continued from page 31)*

***Columbia's Final Flight: STS-107***

*The STS-107 crew (l-r): Mission Specialist David M. Brown, Mission Commander Rick D. Husband, Mission Specialist Laurel Blair Salton Clark, Mission Specialist Kalpana Chawla, Payload Commander Michael P. Anderson, Mission Pilot William C. McCool, and Payload Specialist Ilan Ramon. Credit: NASA.*

*Note: For information on the Columbia Research and Preservation Office, visit* ***http://columbia.nasa.gov***

that helped to prove that a piece of insulating foam from the large exterior fuel tank of the shuttle system had broken free 82 seconds after launch and struck the leading edge of the orbiter's left wing.

The final CAIB conclusion was that the foam impacted panel 8 of the RCC thermal protection system on the orbiter's leading edge. That anomaly permitted the penetration of hot reentry gases and led to the loss of Columbia and its crew. The impact against RCC panel 8 produced a hole in the panel roughly 16x16 in. Analysts estimated that a hole 10 in. across could have caused a loss of the orbiter on reentry.

During Columbia's fatal return to Earth, superheated air entered the leading-edge insulation and progressively melted the aluminum structure of the left wing, until increasing aerodynamic forces led to loss of control, failure of the wing, and disintegration of the orbiter.

"We stated very explicitly what happened," Hubbard says. The test put an exclamation point or period to our physical cause statement. There are no disclaimers in there. There's no 'most probable'… there's no 'we believe that.'"

There are risks that go with space travel, Hubbard emphasizes. "It's a 'one strike and you're out' business. It's very unforgiving. I think one of the principal lessons from Columbia was that organizations that attempt to do very bold and potentially risky things need to be learning organizations."

## Beware the new normal

Ciannilli also points to lessons learned. "We learned that we didn't understand some of the hardware as well as we thought we did. Some of our testing was based on data from 25 or 30 years earlier. That data and modeling were not as complete and as accurate as we thought," he says. "As the flight history went on and different experiences were gained over 30 years, we didn't really update all the models."

Some of CAIB's findings clearly show that there is a need to "watch your data," Ciannilli says. "Keep things updated. Keep vigilant on what your data is really telling you. Off-nominal things can, over time, look normal. Keep an eye on those things that aren't good that creep into becoming 'the new normal.'"

For Ciannilli the experience gained in tending the Columbia Research and Preservation Office leads to a central observation: "There's so much to share, so much to learn, and so much to grow from," he says.