Failure *is* an option

JSC group learns how materials break in order to build safer spaceflight hardware

by Catherine E. Borsché

Sherlock Holmes may not be employed at Johnson Space Center, but there are many individuals in JSC's Failure Analysis Team who emulate the famous detective in their everyday jobs.

The Materials and Processes Branch at JSC performs a sort of detective work called failure analysis on aerospace-related parts and hardware. The group analyzes materials for several programs, such as the International Space Station, space shuttle and Crew Exploration Vehicle, as well as facilities such as Ellington Field and the Neutral Buoyancy Laboratory.

The knowledge gained from failure analysis can be used to prevent failures, improve future designs and understand environmental and service effects on material behavior.

In other words, the analyses conducted by the group help ensure the safety of equipment used in space as well as on the ground.

"Our work benefits the space program and exploration because materials troubleshooters make our hardware safer," said Heather Fireman, materials and processes engineer. "As long as we are building structures and machines, there is the potential for problems with the materials composing them. Properly diagnosing the problem and recommending changes to avoid it in the future are key to getting the most out of our advanced materials."

The most accepted approach to failure analysis is the funnel approach. This track starts with an infinite number of possibilities and uses a systematic process of elimination by various test methods to determine the cause of a failure.

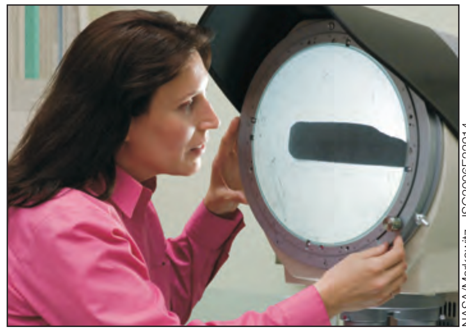
"Our goal is to determine the root cause of the failure (in the structure); that way, we can then provide recommendations for improvement for future processes and materials," Alma Stephanie Tapia, metallurgical and materials engineer, said. To do that, the team goes through a variety of steps during the failure analysis, some of which include identifying the way an item failed, finding the site of the failure and figuring out where the failure started.

In general, the investigation process begins with the most nondestructive techniques and then proceeds to more destructive techniques, gathering data from each test throughout the process. However, each investigation is unique and testing techniques are often selected based on a customer's needs and the shape and size of the material being investigated.

"Basically the first step is usually a visual inspection of the part," Tapia said. "You do measurements to make sure you understand the dimensions of it and take initial pictures so you understand what you're getting."

In addition to visual inspections, the team does testing on the object while it is still intact. Afterwards, methods become more "destructive" to get a better picture of the failure from an internal point of view.

"I do some scanning electron microscopy and some metallic materials microstructural evaluation," said Glenn Morgan, aerospace engineer for the Engineering and Science Contract Group. Morgan said that he utilizes "metallography techniques such as sectioning, mounting, grinding, polishing and etching."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Top photo: ***Leslie Schaschl measures the dimensions of a failed part with an optical comparator.***

Bottom photo: ***Mike Kocurek prepares a compression test.***

For example, "we do cross sections of (a piece of hardware) to look at the microstructure," Tapia said. Using this technique enables the team to "get a close view of what's inside the material."

On the mechanical side, testing can involve cooling, bending, fatiguing and other methods to evaluate the hardness of the object to various stressors.

The team members also use complex equipment to perform their analyses.

"I use a Light Optical Microscope to photographically document the specimen, which is typically a piece of hardware from the space shuttle, space station, Ellington Field aircraft such as a T-38 or institutional support hardware. I also do lots of digital photography to record the 'as-received' condition of the hardware," Morgan said.

It is very important for a failure analyst to remain objective during the testing and not jump to unwarranted conclusions.

"The more failure analysis that you perform, the more reserved a failure analyst is in making conclusions," said John Figert, metallurgical engineer and Failure Analysis Team lead. "Analysis results often are not what you expect, so it is very easy to make the wrong conclusion prematurely. Once you burn yourself once or twice badly, you often learn wisdom."

Tapia echoed the same thought. "You can never know—never assume. Sometimes you can have an idea of what might have caused a failure, thinking, 'It looks like it might be this,' but you have to always go check it out, and you might find something completely different. Occasionally projects that seem like old projects might shed new light on something you've done before," Tapia said. "It's a constant discovery process."

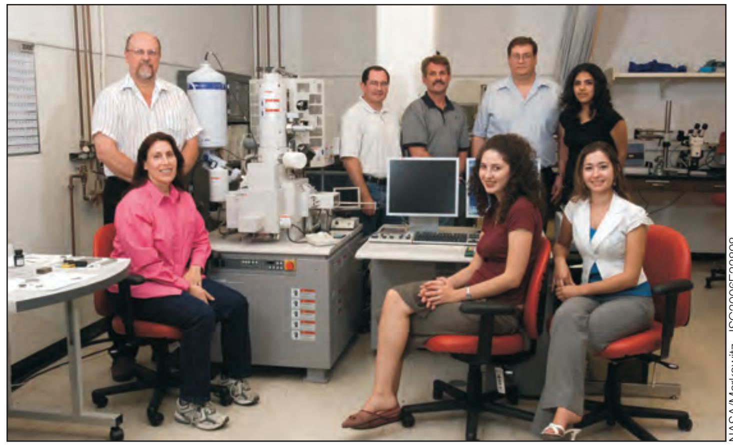
The investigators said they enjoy their detective work, and are invigorated by the challenges they face when it comes to deciphering a unique problem.

"I mostly enjoy learning about the many ways materials can fail, as pessimistic as that sounds!" Fireman said. "We are concerned with real-world problems of materials engineering—the humid, salty air at the Cape (Canaveral) as a corrosion threat, or the tendency for small surface imperfections to raise local stresses and initiate cracks. The challenge is to make materials work in spite of all these things."

Although experts in the field, the team members unearth many unknowns that often make for interesting scientific revelations.

"I am quite frequently surprised by some of the findings. We have the best minds in the world designing and fabricating flight hardware, yet the environment in which we operate is so hostile that we still have some unanticipated results," Morgan said.

As Morgan indicated, the Failure Analysis Team is crucial for the future of exploration as NASA wishes to explore even bigger unknowns in the universe. "(Our) work benefits all the programs in that it allows us to make better decisions in material selection and hardware design in support of fabricating the safest systems for the future of manned spaceflight," he said.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The Failure Analysis Team: back row, from left are Glenn Morgan, Rodrigo Devivar, Mike Kocurek, John Figert and Daila Gonzalez. Front row, from left are Leslie Schaschl, Heather Fireman and Alma Stephanie Tapia. Not pictured: Gordon Fowkes, Louis Hulse and Penny Gardner.


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Failure Analysis Team Lead John Figert places a fractured surface under a stereomicroscope.

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Jeff Hanley talks about the Constellation Program

by Kelly Humphries

NASA established the Constellation Program in October 2005 to turn the ideas of the 60-day Exploration Systems Architecture Study (ESAS) into a sustainable human space program. Veteran flight director Jeff Hanley is leading the agencywide team that is meeting the challenges of developing spacecraft for a new generation of explorers.

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Cargo launch vehicle concepts

Top photo is an artist's rendering of a cargo launch vehicle blast off, carrying a lunar lander and a "departure stage" needed to leave Earth's orbit.

Next is a concept of solid rocket booster separation following the launch of a cargo launch vehicle, which will carry a lunar lander and a "departure stage."

Cargo launch vehicle illustrated in orbit after releasing the covering for the lunar lander.

This artist's rendering represents a concept of a cargo launch vehicle as the first and second stages separate in Earth orbit.

1 ***What's the status of the Constellation Program today?***
We're right where we ought to be, considering that the program office has only been in existence for a little over six months. I've been focusing my efforts on creating a structure for the program that's based on the successful model of Apollo, establishing our key requirements based on our long-term needs, goals and objectives and identifying where in NASA we have the skills and facilities to make it all happen. The next step is to finish defining the requirements, finalize the designs and start building hardware. Throughout the rest of the process, we will continue component testing that's already begun and get ready for integrated testing of major elements.

2 ***How are you organizing the program?***
We've set up an organization structure that's very similar to what George Mueller and Sam Phillips did on Apollo, but adds an Advanced Projects Office that will spin off additional projects later on. The basic structure includes the following offices.

- The Program Planning and Control Office, led by Barry Waddell, will be the policy and procedures police for the program.
- The Test and Verification Office, led by Bill Arceneaux, will validate all of the development work.
- The Operations Integration Office, led by Bob Castle, will make sure we integrate mission operations through the development, test and flight phases of the program.
- The Systems Engineering and Integration Office, led by Chris Hardcastle, is establishing and documenting all of the requirements for the program.
- The Safety, Reliability and Quality Assurance Office, led by Lauri Hansen, will make sure that everyone at NASA and our contractors stay vigilant when it comes to safety.

Matrixed with these will be the Crew Exploration Vehicle (CEV) Project Office, led by Skip Hatfield at JSC; the Launch Vehicle Project Office, led by Steve Cook at Marshall; the Ground Operations Project Office, led by Tip Talone at Kennedy Space Center; and the Mission Operations Project Office, led by Dennis Webb here at JSC.

The Advanced Projects Office that Carlos Noriega is in charge of will spin off other project offices for landers and other surface support systems.

I also have some key help from my deputy, Mark Geyer, and two associate managers, Tip Talone at KSC and Todd May at Marshall. Deb Neubek is my chief of staff for technical issues, and Brenda Ward is my assistant manager for program integration. Marsha Ivins is my special assistant for technical integration and the lead Astronaut Office representative to the program.

3 ***What does the Constellation architecture look like now?***
We're building on the great work that Mike Griffin and the ESAS team did last spring to put together a plan for an affordable, sustainable fleet of vehicles that can take over soon after the shuttle is retired at the end of the decade. The systems we build need to be as simple and as low-mass as we can make them and be maintainable along the way. Our current designs start off with the CEV, which is an Apollo-like capsule, only bigger, that can carry up to six crew members to the space station or four to the moon.

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In a pose reminiscent of a famous photograph from the Apollo era, NASA Exploration managers hold a wind tunnel model of NASA's next spacecraft during a recent tour of Langley Research Center. From left are: NASA Deputy Associate Administrator for Exploration Doug Cooke, CEV Project Manager Skip Hatfield, CLV Project Manager Steve Cook, Langley Exploration and Flight Projects Head John Herrin and Constellation Program Manager Jeff Hanley.