National Aeronautics and Space Administration

MARSHALL STAR

Serving the Marshall Space Flight Center Community

April 14, 2011

Director's Corner

When the wheels stop, it will be a time for a lot of pride

On the 30th anniversary of the first space shuttle launch, this special issue of The Marshall Star tells the story of the Space Shuttle Program, its many contributions to human spaceflight and the nation, and Marshall's leading role in its development, operation and ultimately its success.

As the shuttle program gets closer to retirement, I find myself becoming more nostalgic and a little bit emotional about it.

Most of my career was spent supporting shuttle propulsion. My first engineering job was as a student co-op for a contractor working on shuttle engine testing at Marshall in 1988. I went on to support shuttle in various roles, including manager of the Space Shuttle Propulsion Office at Marshall. Whatever I know about propulsion, space hardware, teamwork, or leadership can be mostly traced back to my shuttle experience.

Technically speaking, the shuttle is an amazing vehicle with unmatched versatility. It carried people, cargo, space probes, upper stages, space telescopes, and laboratories. It launched satellites, repaired them, and even returned them. Among the shuttles' heroic crews were our first women and minorities into orbit, as well as the astronauts and cosmonauts of many other nations.

Although the main engines that I worked on are often mentioned as the most complex individual component based on their complexity, efficiency, and reusability, I can't point to a single greatest technical challenge or achievement. The most impressive achievement to me was the integration of all the pieces and getting them to all work together – going from zero to 17,500 miles per hour in eight and a half minutes.

Today's shuttle isn't the shuttle we launched in 1981. The propulsion elements in particular underwent several upgrades to improve safety and performance. The work kept our engineers sharp, and it made us better. The shuttle itself and its payloads are well-known. For all that it accomplished, its context in ongoing human exploration may be more important. The shuttle was our longest-running human space flight program and the longest of any except Soyuz. Through the shuttle program, we learned about operating a reusable vehicle, long-term operations, incorporating updates prudently, building structures in space, and repairing them. We learned about success, and we learned hard lessons from failure.

My memories about the hardware and history, however, are embedded in my memories of the people. The shuttle didn't build or fly itself. I don't think it's an exaggeration to say the shuttle is a personal story, whether you devoted your career to keeping it flying, from STS-1 to STS-135, or whether you drove down to Kennedy Space Center one time in your life just to stand on the beach and watch a launch.

Something that impressed me in 1988 and that remains a strong memory is the camaraderie of the Marshall shuttle team. They are so focused on the mission, so focused on safety. They're the real marvel of the shuttle program. They've stayed focused through dozens of successful missions and recovered strong from the Challenger and Columbia tragedies. Everybody felt like we had each other's backs. It's rare to work where the people feel that true team spirit. This year, despite uncertainty about the future, they will fly STS-135 with the same focus, dedication, passion, professionalism, and teamwork as the STS-1 people did, the same as the Apollo people did for that matter, because that's the Marshall legacy.

Watching a shuttle launch, particularly for the first time, was an intensely emotional experience greater than the sum of all the fire and smoke and thundering hardware. After one particular launch, I saw a friend of my family at the Cape. She had goose bumps and tears were running down her face and she said, "What a great symbol of what we CAN do as a nation in a world where we hear a lot about what we can't do." That's how a lot of people felt.

A lot of us have suppressed our emotions about the shuttle retirement, but it's getting harder as last flight gets closer. Discovery is home to stay. Soon, Endeavour and Atlantis will fly one last time. Right now we're all just doing the unemotional engineer thing and keeping our heads down in the data. When the last shuttle lands, after the crew calls, "Wheels stop", it will be a time for a lot of pride and celebration, and, yes, a few misty eyes. To all who have been part of the last 30 years, I thank you and hope you will take time to reflect on your part of the great mission of the space shuttle.

Robert Lightfoot
Marshall Center Director

STS-1: 30 years ago

A new chapter in the exploration and use of space

By Mike Wright

In Huntsville, Ala., as well as other places, Sunday morning often means time to enjoy the Sunday paper or prepare for church. But Sunday morning April 12, 1981, dawned different in Huntsville as well as all over the world. Dawn brought the launch of Columbia, America's first space shuttle – a goal that people at Huntsville's Marshall Space Flight Center and other NASA locations had dedicated themselves to for more than 10 years.

As lift off approached, Marshall engineers monitored consoles in Huntsville while others from Huntsville participated at the launch site in Florida. Their job was to give the green light to the shuttle propulsion elements that Marshal's engineers and contractors had spent a decade perfecting. At 3 seconds after 6 a.m. CST the mission, designated STS-1, lifted off from Pad A of Kennedy Space Center's Launch Complex 39.

"Now we can breathe," said Jack Lee, who served as deputy director of the Marshall Center in the 1980s and as director in the early 1990s. Rising on a pillar of orange flame and white steam, the shuttle cleared its 348-foot-high launch tower in 6 seconds and reached Earth orbit in about 12 minutes.

STS-1 launch

"It was a beautiful happening," Lee said. The solid rocket boosters and external tank had been shed prior to orbit. "Man, that was one fantastic ride," later exclaimed STS-1 Pilot Robert Crippen. According to STS-1 Commander John Young, the shuttle main engines, solid rocket motors, and external tank worked in an outstanding manner. "We got a smooth push out of the launch stand," added Crippen.

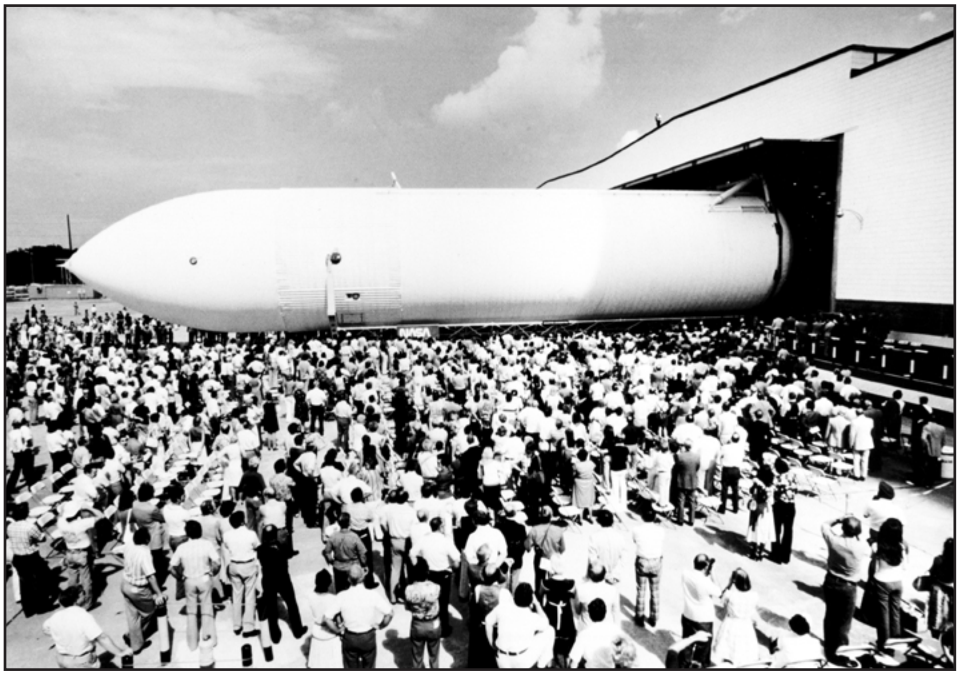
Dr. William R. Lucas, then serving as director of the Marshall Center, referred to STS-1 as the start of "a new chapter in the continuing account of man's exploration and use of space." STS-1 was the first American-crewed space flight in nearly six years. Huntsville, along with the rest of the nation, was captivated by the first flight of the space shuttle, a craft unlike anything America had previously seen. Some 80,000 people viewed the launch from east central Florida.

The story of the vital role that the Marshall Center played in designing, developing, and testing the propulsion elements for the space shuttle represented an entirely new chapter in the center's history. It was a chapter that ushered in a new era in human spaceflight.

"You know when you ride a launch vehicle, the future standard launch vehicle of the United States of America, if it doesn't work right, if all those engines don't work right, you don't get very far down range. The space shuttle worked perfectly," said Young.

The concept of a reusable space shuttle was particularly appealing as a vehicle to ferry people and supplies to and from orbit. With its expertise in large launch vehicles and propulsion systems, it was only natural that the Marshall Center should play a major role in the space shuttle program.

Wright is the Marshall Center historian



Rollout of first external tank

Shuttle saw many improvements over the years

By Mike Wright and Jim Owen

The Space Shuttle Program, with only two flights remaining on the manifest, is finishing strong. For more than 30 years, improvements in the Marshall Space Flight Center's space shuttle propulsion system – the external tank, solid rocket boosters and solid rocket motors and the space shuttle main engine – have made the shuttle safer and better.

Each element has undergone upgrades that have improved performance, reliability and safety in a relentless pursuit of improvement.

Space shuttle external tank

- In the early 1980s, the External Tank Project office implemented a redesign called "light-weight tank," reducing the structural weight from 76,000 to 66,000 pounds – a significant accomplishment given that the tank flies to orbital velocity with the shuttle orbiter, and each pound saved results in an additional pound available for payloads. The first light-weight tank was launched in 1983.
- In the early 1990s, a composite nosecone, manufactured at the Marshall Center, was added to eliminate the need for thermal protection material and a possible debris source. *(See story on page 10 about nosecone manufacturing at Marshall.)*
- During the mid-1990s, additional payload capability was required to meet International Space Station payload requirements. The External Tank Project again implemented a block redesign called "super light weight tank," which removed an additional 7,500 pounds of structural weight by using a light-weight aluminum lithium alloy. This significant accomplishment enabled partnership with the Russian Space Agency for assembly of the space station in a high-inclination orbit. The first flight of the super light-weight tank was in 1998.
- After engineers completed proof pressure tests of an aluminum lithium test article to verify the tank design at Marshall, NASA Administrator Dan Goldin phoned astronaut Shannon Lucid aboard the Russian Mir in 1996, telling Lucid, "Marshall just completed the qualification test on the aluminum lithium tank. We have a 200 extra pound margin … to take payloads up to the International Space Station." This was a significant step toward the first launch of components to assemble the International Space Station.
- Following the Columbia accident in 2003, the External Tank Project implemented significant design and processing improvements to reduce ascent debris risk. The bipod fitting that attaches the tank to the orbiter was redesigned, heaters were added at strategic locations to reduce ice formation and foam ramps were redesigned or removed. A camera was added to provide video during ascent flight, enabling enhanced post flight assessment of ascent debris performance. These changes resulted in the risk due to ascent debris being reduced by more than a factor of 100, a remarkable achievement.
- In a spectacular Independence Day display, space shuttle Discovery lifted off from the Kennedy Space Center July 4 on its STS-121 mission to the space station – the first of the year and the second Return to Flight mission – and successfully tested shuttle safety improvements. The 13-day mission also produced never-before-seen, high-resolution images of the shuttle during and after launch.
- Friction stir welding, a process that uses a rotating pin tool to soften, stir and forge a bond between two metal plates, was implemented in the external tank manufacturing process. Because the method does not melt the material as fusion-welding techniques do, the weld has excellent mechanical properties and exhibits very little shrinkage or distortions even in long welds. The first friction stir welded tank flew in 2009.
- Another improvement during the program was the cryogenic insulation system, which serves the dual purpose of thermal protection from ascent heating. The protection system was successfully reformulated several times to comply with environmental regulations.
- In 2005, Hurricane Katrina devastated the Gulf Coast and significantly damaged NASA's Michoud Assembly Facility in Louisiana, where the tanks are manufactured. Recovery from this natural disaster was a significant achievement and production was resumed within a month. During the program, 139 tanks were manufactured for flight and testing, concluding with a remarkable record of continuous improvement.

Reusable solid rocket motor

The space shuttle solid rocket motor, the first and only human-rated solid rocket motor, has also undergone significant redesign and upgrades during the life of the program. Improvements began in 1983 with the high performance motor that included increasing the motor chamber pressure, reducing the nozzle throat, increasing the nozzle expansion ratio and modifying the propellant grain-inhibiting pattern.

These enhancements resulted in increasing the payload capacity by 3,000 pounds. The first high performance motors were flown on STS-8 in 1983. Following the space shuttle Challenger accident in 1986, the redesigned solid rocket motor incorporated significant safety improvements and flight performance has been a remarkable success.

*See **Improvements** on page 5*

Improvements *Continued from page 4*

- Motor case and nozzle joint sealing systems were redesigned, with the addition of numerous features to add sealing system redundancy and robustness, including improved case metal hardware with a capture feature and third O-ring. An innovative insulation feature called a "j-leg," which prevents gas intrusion within the joint, was added.
- Heaters were added to thermally condition sealing systems.
- Processing controls, subscale and full-scale ground-scale testing and a thorough post-flight assessment process have added to system safety.
- Keys to process control included chemical fingerprinting to assess the consistency of delivered materials required for manufacturing the motor and implementation of process failure modes and effects analysis.
- A ground-testing program included small motor testing at Marshall and the contractor facility in Utah. Full-scale motor testing also was conducted in Utah to assess material and design changes and special instrumentation to characterize performance.
- In 2003, a space shuttle solid rocket motor was tested and pushed beyond typical launch performance boundaries. The five-segment test motor test, which ran for 118 seconds and generated more than 3.6 million pounds of thrust, performed flawlessly.
- By the end of the program, 52 static motors had been tested.
- Post flight assessment provided thorough evaluation of hardware condition, the ability to identify any items of interest and initiate corrective actions if needed. This capability is unique among solid rocket motors, as the space shuttle solid rocket motors are recovered for reuse.
- Other innovative design improvements included use of a carbon fiber rope thermal barrier material in the nozzle joints implemented in 2008.
- Improved resiliency O-ring material implemented in 2009.
- An innovative intelligent pressure transducer was flown to assess pressure oscillations for future motor designs.

Solid rocket boosters

The solid rocket boosters – which integrate subsystems needed for ascent flight, entry and recovery of the combined booster and motor system – also have been significantly improved during the past 30 years. Improvements have been made in the thrust vector control, auxiliary power unit, avionics, pyrotechnic, the range safety system, parachutes, thermal protection, forward and aft structures and recovery systems.

The space shuttle solid rocket boosters are the only recoverable and refurbishable system ever developed and flown. During the program, recovery and post-flight operations were a challenging and essential component of accomplishing flight operations, achieving reliability and implementing continuous improvement. Challenges included subsystem integration and designing for severe loads, including water impact. Several of the subsystems evolved during the program through design changes:

- The parachute system, essential for booster recovery, was redesigned with larger parachutes in 1983.
- The booster thermal protection system has evolved from a Marshall sprayable ablator initially used in 1982 to a Marshall convergent coating first used in 1996.
- The aft skirt structure was modified in 1998 to add a bracket to increase structural safety.
- The external tank attach ring was redesigned in 1988 from a 270-degree to a full 360-degree ring, and in 2006 the material was changed to improve structural margins.
- The solid rocket boosters provided stand-alone data acquisition systems beginning in 1996 to record flight accelerations and recovery loads.
- Enhanced data acquisition systems to support the post-Columbia Return to Flight external tank modifications flew in 2005; these systems also were used in 2008 to acquire pressure oscillations and structural response data for use by future programs.
- Cameras were added in 1996 to observe parachute performance, and again in 2005 to observe ascent debris performance.
- The command receiver and decoder, an essential feature of the range safety system, was redesigned in 2007.
- Frangible nuts, used in the space shuttle pad holddown and release system, were redesigned in 2008. They feature an innovative pyrotechnic design to ensure proper timing during lift off.
- Environmental compliance was implemented for coatings, thermal protection systems and for post-flight operations.
- Booster separation motors were redesigned and first flew in 2008. This was accompanied by conducting a substantial ground-test program to certify the new motors for flight.
- The thrust vector control system auxiliary power unit incorporated a fuel pump redesign in 2011.

Space shuttle main engine

The amazing space shuttle main engine implemented evolutionary upgrades during the 30 year program, resulting in a four-fold improvement in predicted reliability, many improvements in component life and reduced maintenance time.

- The space shuttle main engine transitioned from its first manned orbital flight configuration to a phase II configuration in 1983. The phase II engine logged 231 engine flights and included improvements to the controller to increase memory, main injector improvements, turbine blade improvements within the turbopumps and additional nozzle insulation.

*See **Improvements** on page 11*

Accomplishments of this amazing spaceship...

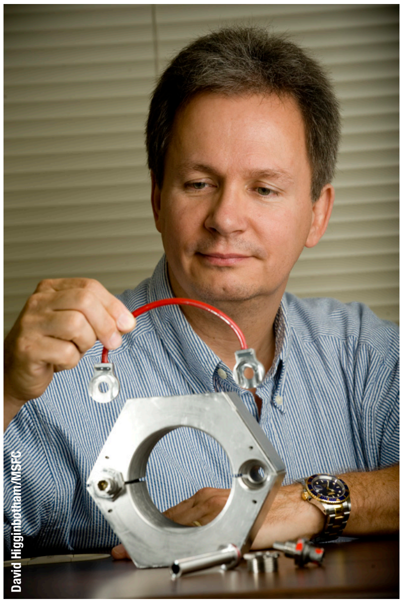
From left, Shuttle Propulsion Office team members Chris Riley, United Space Alliance-Huntsville; Mike Mitchell, Marshall Space Flight Center Systems Engineering and Integration Project office; Tannen Vanzwieten, Marshall Engineering Directorate; and Jeff Painter, United Space Alliance-Kennedy, on the 295-foot-high fixed service structure at launch pad 39A during STS-133 prelaunch debris mitigation walkdowns at Kennedy Space Center, Fla.

Chad Bryant, left, External Tank Project engineer, and Greg Vinyard of Lockheed Martin, prepare to install External Tank ET-125's feed through connector in a pressure vessel at the Marshall Center's Test Stand 300. The connector was removed from the tank on the launch pad at the Kennedy Space Center, Fla., in December 2007 and shipped to Marshall for inspection, test and evaluation. Open circuits in a feed through connector, part of an engine cut-off sensor, were identified as the cause of false readings that prevented space shuttle Atlantis' launch Dec. 6 and Dec. 9, 2007, on the STS-122 mission.

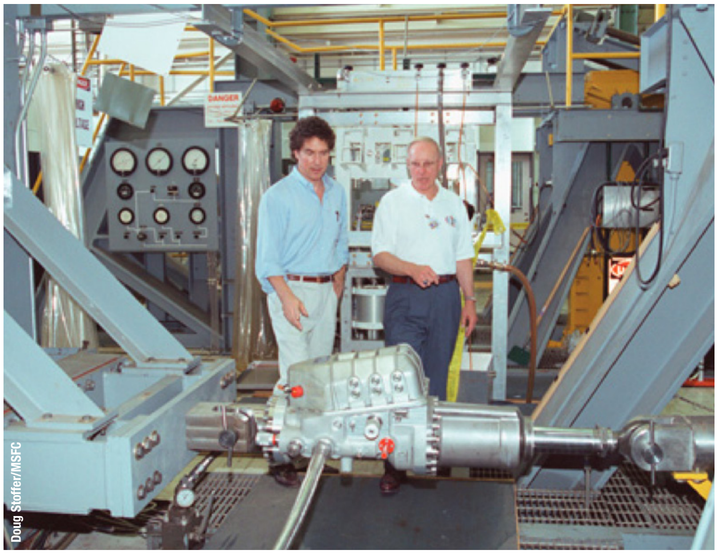
Following their October 2000 mission, astronauts who flew aboard space shuttle Discovery on the STS-92 mission met with Marshall Space Flight Center Director Art Stephenson, second from left, during their visit to the center. From center, crew members including Pilot Pam Melroy; Mission Specialists Leroy Chiao and Jeff Wisoff; and Commander Brian Duffy autographed the wooden shuttle model carved by Scott Phillips, left, an engineer with Lockheed Martin Space Systems of Huntsville.

Following the merger of the Solid Rocket Booster and Reusable Solid Rocket Motor project offices in January 2007, Project Manager Jody Singer displays a new sign for the office in Building 4202. The projects were combined to strengthen the shuttle organization.

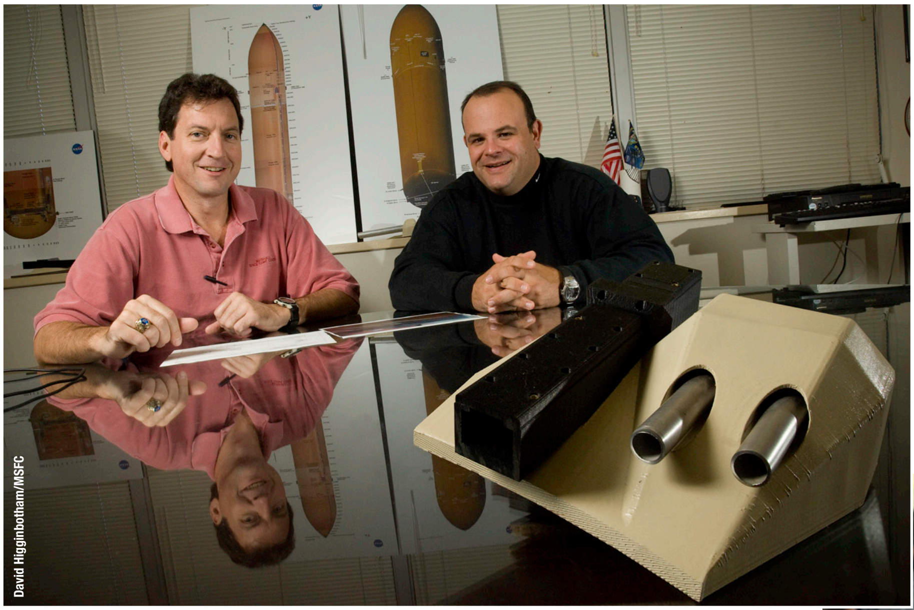
...and the generations of people who made it possible



Joe Gentry, an engineer in the Reusable Solid Rocket Booster Project office, led a team that redesigned a pyrotechnic device on the shuttle booster hold-down posts. The redesign flew the first time on the STS-126 mission, which launched in November 2008.



In July 2001, Parker Counts, right, manager of Marshall's Solid Rocket Booster Project Office, and David Wood, also of the project office, inspected the Component Development Lab in Building 4656 prior to tests on the solid rocket boost thrust vector control proposed upgrade, one of four shuttle propulsion enhancements.



Tim Owen, left, an engineer in the External Tank Project Office, and John Rector, safety and mission assurance lead, participated in an effort in 2007 to repair external tank ET-120 and recertify it for flight. The tank had been used as a dissection test article during the STS-114 foam loss investigation and required extensive repairs. Owen and Rector display a model of a redesigned liquid hydrogen tank ice/frost ramp. The ramps were redesigned to minimize foam loss and became the basis of a new design for all future tanks. ET-120 flew on STS-120, which launched Oct. 23, 2007.

Steve Cash, Shuttle Propulsion Office manager, helps Chuck "Santa Claus" Lovell distribute door prizes at a 2010 holiday event at the Building 4316 Activities Center.

From left, Sharon White, Yolanda Harris and Stephanie Lacy-Conerly at the Shuttle Awards Appreciation ceremony and lunch in August 2006.

Marshall's Resident Office at Kennedy shuttle 'ambassadors'

By Lori Meggs

When a space shuttle sits on the launch pad ready for lift off, some Marshall Space Flight Center "ambassadors" have done their job to ensure the propulsion systems are safe to fly.

The team members in Marshall's Resident Management Office at Kennedy Space Center, Fla., are those ambassadors. They are an extended family from Marshall's Shuttle Propulsion Office – serving as the "eyes and ears" for the Marshall Center. They monitor and supply technical design expertise to all the processing and launch-related concerns for the main engines, external tank, solid rocket motors and boosters. In addition, they provide support to the entire center on numerous tasks and actions.

Beginning with the first space shuttle launch, the STS-1 mission on April 12, 1981, the Marshall Resident Management Office team has helped prepare NASA's shuttle propulsion systems for each launch.

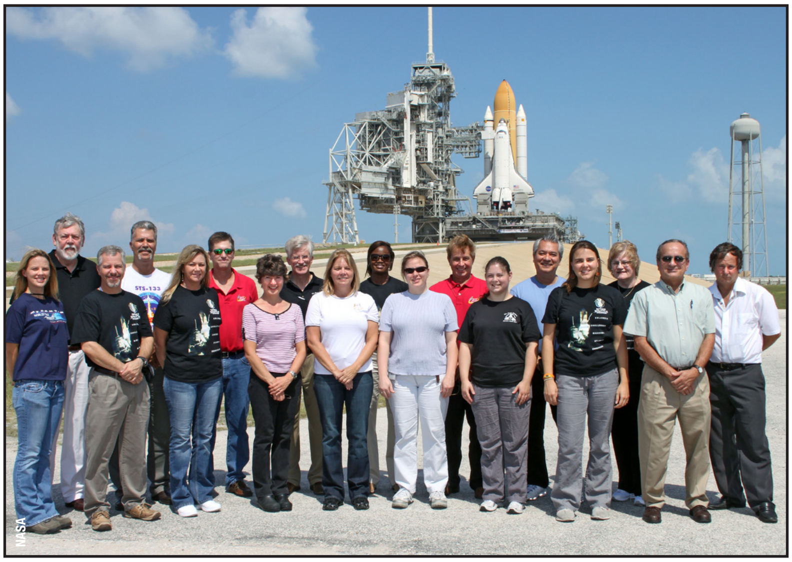
"Our office was created to locate Marshall design engineers onsite as liaisons with the shuttle propulsion contractors and serve as ambassadors to the Kennedy Space Center," said Jolene Martin, manager of the Marshall Resident Management Office since 2006. "We track the assembly and testing of propulsion hardware, monitor launch countdown, participate in post-flight analysis and facilitate the resolution of any issue that may arise. We ensure the propulsion managers are aware and involved in concerns with their hardware so they can ultimately fulfill their Certificate of Flight Readiness responsibility."

Over the years, if hardware design deviations were discovered, or production errors were detected, the team's expertise has helped with a resolution to maintain a world-wide visible launch schedule.

"These Marshall team members are just incredible and I can't thank them enough," said Steve Cash, manager of Marshall's Shuttle Propulsion Office. "Their strong dedication to be there for us every step of the way, and to provide approvals and concurrences on shuttle hardware, have been essential to our mission. Job well done."

While other NASA centers have offices onsite at Kennedy, Marshall's is unique due to the in-depth involvement in hardware processing. More than 50 office team members participate in tests, simulations and launches and work with other Kennedy organizations, including ground operations, launch services and launch integration, to give Space Shuttle Program managers information they need to give a final "go" for launch.

The first employees of Marshall's Resident Management Office at Kennedy Space Center stand near launch pad 39A and space shuttle Columbia prior to its launch April 12, 1981.



Current employees of Marshall's Resident Management Office at Kennedy stand near launch pad 39A and space shuttle Discovery prior to its launch Feb. 24, 2011.

But the team members' jobs aren't over when a shuttle launches. Following a launch, they assist with post-launch retrieval of the solid rocket boosters and in the post-flight assessment and disassembly operations.

"We are proud of our history and it's humbling to look back and see what we've accomplished in supporting the Space Shuttle Program," added Martin. "Our office will continue to be an integral part of Marshall's on-site interface with Kennedy in support of numerous program-related goals and tasks."

Meggs, an AI Signal Research Inc. employee, supports the Office of Strategic Analysis & Communications.

Huntsville Operations Support Center remains key channel for receiving and distributing data for shuttle missions

By Lori Meggs

From Juno in the 1950s to the space shuttle of today, data from space has been transmitted through a Marshall Space Flight Center landmark that most folks at NASA simply refer to as "the HOSC."

The Huntsville Operations Support Center, located in Building 4663, is a multi-mission facility capable of distributing secure mission voice, video and data from space to anywhere in the world.

This historic facility began operating in 1958 in support of the Juno Program, the U.S. Army Ballistic Missile Agency's space vehicle used to launch the first American satellite to orbit Earth. By 1963, work on NASA's Saturn Program led to a need for direct communications between the Saturn development team in Huntsville, the Mission Control Center at the Johnson Space Center in Houston and the launch operations team at the Kennedy Space Center, Fla. Marshall managers agreed to provide a flight control team at the Johnson Center for the Saturn launch vehicle, while providing engineering support in Huntsville. This type of mission support continued throughout the shuttle era.

In the Shuttle Engineering Support Center in the HOSC, Marshall engineers staff consoles to monitor real-time data from the space shuttle during pre-mission testing, countdown and launch. The shuttle team evaluates and helps solve technical issues that might occur and decides whether Marshall-developed propulsion systems – the external tank, the reusable solid rocket boosters and the space shuttle main engines – are "go" for launch.

"It's exhilarating to work in a place with this much history," said Scott Schutzenhofer, an engineer in the Shuttle Engineering Support Center. "The HOSC systems have proven themselves launch after launch and we are equipped to handle any situation that may arise."

> *"It's exhilarating to work in a place with this much history. The HOSC systems have proven themselves launch after launch and we are equipped to handle any situation that may arise."*
> *— Scott Schutzenhofer, an engineer in the Shuttle Engineering Support Center*

Sensors aboard the shuttle provide more than 11 million measurements of information about the health of these systems. That data is instantaneously transmitted from the launch pad via satellite to the HOSC and the shuttle support center. This occurs both while the vehicle is on the launch pad and during ascent. The shuttle engineering team also monitors wind conditions surrounding launch and re-entry.

Approximately 150 Marshall support center personnel monitor the shuttle via a multiplexed satellite system supporting two closed circuit television feeds, one of which allows Marshall engineers to control camera selections. They also have access to more than 25 direct voice communications lines linked to the launch site at Kennedy, Mission Control at Johnson and with shuttle contractor facilities across the country where propulsion system elements are manufactured.

In addition to its space shuttle launch activities, the HOSC was the command post for Space Shuttle-Spacelab Program missions in the 1990s, serving as the operations center for Spacelab science missions conducted in the shuttle's payload bay.

In May 1990, the Marshall Center announced that beginning with the STS-35 mission in December 1990, all Spacelab missions would be controlled from NASA's new Spacelab Mission Operations Control Center at Marshall. The facility, a subset of the HOSC, supported the science astronauts on Spacelab in much the same way that Mission Control in Houston supported the flight crew. Marshall also managed the majority of the Spacelab science missions, performing the mission management and mission scientist roles.

The Marshall Center supported more than 20 Spacelab missions. Spacelab was a versatile laboratory that consisted of multiple facilities, components and capabilities, including a pressurized module, unpressurized carriers – called pallets – and other related hardware. Its components were arranged in various configurations to meet the needs of each mission, which were science investigations to demonstrate the capability for advanced research in space.

Marshall controllers and researchers at the Spacelab Mission Operations Control Center directed NASA science operations and sent commands directly to the spacecraft during Spacelab missions. Controllers also received and analyzed data from experiments aboard the vehicle. Hundreds of scientists from around the world worked from the Marshall Center during Spacelab missions.

The lessons learned during Spacelab flights paved the way for space research now being realized aboard today's full-time laboratory in orbit – the International Space Station – where experiments are performed for months instead of just days or weeks at a time.

Meggs, an AI Signal Research Inc. employee, supports the Office of Strategic Analysis & Communications.

The long route to manufacturing

External tank composite nosecones: Only shuttle flight hardware made at Marshall

By Scotty Sparks, Materials and Processes Laboratory

When the first shuttle launched in 1981, external tanks flew with metallic nosecones covered with foam. They were vendor-supplied to NASA's Michoud Assembly Facility in New Orleans, where technicians installed the 56.5-inch-diameter component to the liquid oxygen tank with a series of brackets.

The external tank nosecone is located at the top of the liquid oxygen tank. Because the oxygen tank is the forewardmost component of the external tank and also of the space shuttle vehicle, its nosecone section curves to an ogive, or pointed arch shape, to reduce aerodynamic drag during the shuttle's ascent. The black nosecone contrasts with the rust-colored foam that covers and insulates the remainder of the giant 15-story tank.

In early 1985, the Marshall Space Flight Center's External Tank Project Office – for the purpose of trimming costs and weight from the space shuttle external tank – investigated reducing or eliminating some components containing relatively dense ablator. Ablator is a dense composite material made of silicone resins and cork that dissipates heat by eroding and is applied to areas of the tank subjected to extreme aerodynamic heating – including the metallic nosecone.

The path to production at the Marshall Center

After major tile damage to space shuttle Atlantis occurred during the STS-27 mission in December 1988, an initiative to redesign the nosecone to reduce foam loss from the external tank was accelerated. Following the mission, aerodynamic flight analysis by Johnson Space Center in Houston and orbiter prime contractor Rockwell International, now the Boeing Company of Chicago, predicted that external tank metallic nosecone ablator debris posed a hazard to the orbiter windshield.

Marshall's External Tank Project prioritized the elimination of potential ablator debris to save weight, increase reliability and reduce the number of manufacturing parts. The metallic nosecone would be replaced with a composite, which is a combination of two or more materials consisting of a reinforcing material for strength and stiffness and a resin binding material. The project defined ground rules that specified it would contain no insulation, be a line replaceable unit and a "no cost" change.

By 1992, the project decided development, qualification and flight of a composite nosecone would not primarily be for debris reduction, because the program had reached a comfort level with debris risks associated with the ablator-coated metallic nosecone. The redesign went forward as originally envisioned by the Marshall project office – to address cost and weight considerations and eliminate ablator. A cost savings estimate was commissioned in May 1992 to assess the effort's viability and plans to proceed with the nosecone redesign continued.

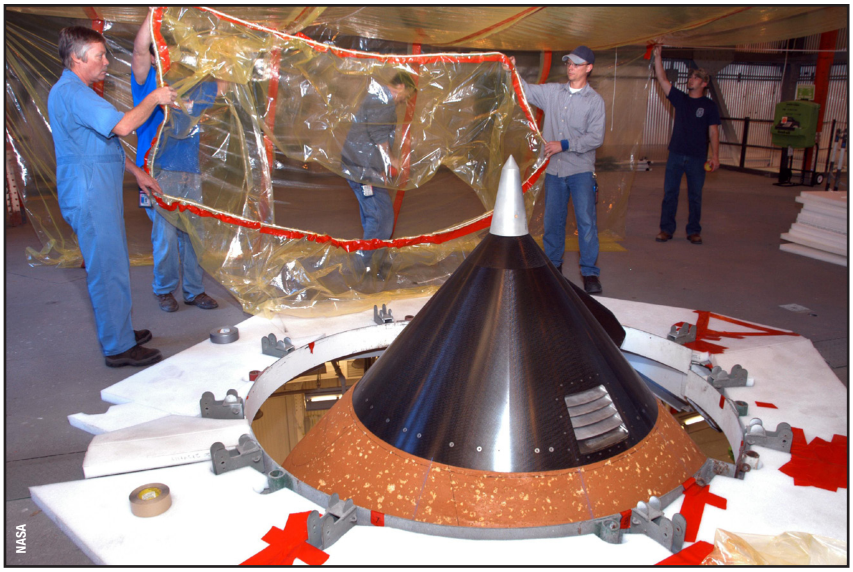
Nosecones would be constructed of composite material that could withstand approximately 1,100 degrees F. temperatures, contain no insulation, would be 10 pounds lighter, increase safety and retire a lightening requirement waiver associated with the vendor-supplied metallic nosecone.

1993 - Marshall gears up for manufacturing

If changes were to be made, manufacturing would shift to Marshall's Materials and Processes Laboratory, which would need to be overhauled if it were to build flight hardware in-house.

The facility was transformed from a laboratory predominantly dealing with materials and process development to one that produced flight hardware. The manufacturing sequence was developed and in place by 1993 to ensure that Buildings 4707 and 4715 were compatible with full-scale nosecone processing and storage.

*See **Nosecone** on page 12*



A close-up view of an external tank nosecone. In March 2007, space shuttle Atlantis was rolled back to the Vehicle Assembly Building from Launch Pad 39A at Kennedy Space Center, Fla., after hail damage to the tank during a severe thunderstorm Feb. 26. Technicians are shown moving protective material to the nosecone to protect it during tank repairs.

Improvements *Continued from page 5*

- The engine transitioned to Block I configuration in 1995 with significant changes including a two-duct powerhead, an alternate high-pressure oxidizer turbopump featuring ceramic ball bearings, a single tube heat exchanger and improved hot gas sensors.
- The Block I featured the new liquid oxidizer turbopump that Pratt & Whitney developed using a casting process that eliminated all but six of the more than 300 welds in the previous turbopumps.
- The Block I included a new two-duct powerhead that improves fluid flows within the engine to decrease pressure and loads.
- The Block I engine included a new single-coil heat exchanger that eliminates seven weld joints inside the engine to reduce wear, maintenance and post-flight inspections.
- The Block I incorporated new ball bearings made of silicone nitride, a type of ceramic material, instead of steel. This new bearing material is 30 percent harder and 40 percent lighter than the old steel bearings and provided an ultra-light smooth finish to decrease operating friction.
- A Block IIA configuration flew in 1998 with a large throat main combustion chamber, ceramic ball bearings in the low pressure oxidizer turbopump and improvements in the main injectors. The large throat combustion chamber reduced internal pressures in the space shuttle main engine, leading to reduced operating environments and improved component life.
- The Block II configuration added a new high-pressure fuel turbopump in 2001. The advanced turbopump featured precision castings intended to significantly reduce welds in the pump. Engineers aimed their work at increasing pump operating margins and facilitating fabrication, assembly and maintenance.
- The Advanced Health Management System, which flew the first time in 2006, interrogates the high-pressure turbomachinery during flight to detect precursors to a problem, and in the event of a problem, is capable of shutting an engine down prior to failure.
- Marshall's Hardware Simulation Laboratory provided hardware and software verification for all main engine controller upgrades and software changes throughout the life of the program.
- Development and operational ground testing, conducted at Stennis Space Center in Bay St. Louis, Miss., and Santa Susana Field Laboratory in California, was a key element of achieving success.
- Marshall initiated a space shuttle main engine technology test bed program to test fire highly instrumented space shuttle main engine components in 1988.
- The space shuttle main engine reached a significant milestone in 2004 when it surpassed one-million seconds of successful test firings and launches. The space shuttle main engine has compiled a remarkable record of demonstrated reliability and successful flight operations.

Integration efforts performed at the Marshall Center during the 30-year program include propulsion system performance assessment, evaluation of natural environments including the ground lightning monitoring system and day-of-launch winds assessments, computational assessment of liftoff debris risks, imagery analysis, and many technical disciplines contributing to anomaly resolution and risk assessment. The Huntsville Operations Support Center provided real time day of launch support for all shuttle missions.

At the Marshall Center, all technical disciplines improved capability during the 30 year program. Design, analysis, test, materials and processing capabilities improved with application of advanced technologies, combined with the significant technical challenges posed by the Space Shuttle Program. For example, computational fluid dynamics emerged as an analysis and design tool – unheard of in the 1970s but routinely used in aerospace design today. Many disciplines contributed to safety of flight improvements with new technology including computer aided design and manufacturing, non-destructive evaluation techniques, failure analysis and fracture control methods and liquid and solid propulsion systems analysis.

The Marshall Center also provides the material used for space shuttle wing repair, first flown on STS-114 in July 2005. The repair material is dubbed "NOAX," for non-oxide adhesive experiment, and could be used if needed during a mission to repair the orbiter wing leading edge prior to reentry.

During the program a number of project management processes were implemented and improved. Technical performance, schedule accountability, cost control, and risk management were effectively managed and implemented. Perhaps the most important aspects of success were related to relationships developed with the prime contractors, which evolved to become very successful government/industry partnerships. Safety and mission assurance, evaluation of hazards and assessment of risk became routine, and continuous processes were evaluated as part of each mission's certification of flight readiness.

In 2006, Robert Lightfoot, then manager of the Shuttle Propulsion Office, later Marshall Center director, commented on the STS-121 Return to Flight mission, Marshall's role in improving the system and of plans to end the Space Shuttle Program. "We're so busy trying to finish what we are doing and we've got lots to do between now and then. And we're not going to stop until the wheels stop on the last mission."

Wright is the Marshall Center Historian. Owen is Chief Engineer of the Shuttle Propulsion Office.

NASA Student Launch Projects activities set for April 15-16

Student participants in the NASA Student Launch Projects rocketry challenge are in North Alabama this week. On April 15, from 11 a.m. to 1 p.m., they'll display their rockets, complete with working science payloads, in Activities Building 4316. All Marshall Space Flight Center team members are invited to attend. Free pizza will be served.

Teams will launch their rockets April 16 at Bragg Farms in Toney, Ala. The event is free and open to the public. For directions, visit http://www.nasa.gov/pdf/531833main_2011_SLP_LaunchInfo.pdf. Launch activities also will be streamed live at http://www.ustream.tv/channel/nasa-msfc.

Teams represent middle schools, high schools, colleges and universities in 25 states. The challenge offers them practical engineering, science and flight operations experience that enhances their classroom learning – and gives them a leg up on future careers that will benefit NASA and the nation.

The Marshall Academic Affairs Office plans and organizes the yearly event, which is sponsored by ATK Aerospace Systems of Salt Lake City, Utah. For more information, visit http://www.nasa.gov/centers/marshall/news/news/releases/2011/11-040.html.

Nosecone *Continued from page 10*

By February 1994, several technical issues had developed and in March 1994, composite nosecone development was cancelled by the project office. It cited technical risk of the nosecone and ogive interface sealing as the primary reason. The laboratory was tasked to resolve the issue while the project continued flying metallic nosecones.

These technical problems were eventually resolved, risks were lessened and the first article was built as a pathfinder in 1995 and several others were to follow. Tests on the first pathfinder indicated it would not be able to withstand the high air flow and temperature extremes during ascent. A different layup and cure process was required to ensure the nosecone would have permeability to allow retention of pressure buildup during high flow and temperature periods.

On Sept 1, 1995, layup started for the first flight nosecone manufactured at the Marshall Center.

Marshall-manufactured hardware leads the way to space on STS-86

In September 1997, the first Marshall-manufactured composite nosecone, a one-piece composite shell 13 pounds lighter than the metal one, flew atop external tank ET-88, leading the way to space on the STS-86 mission. It and all subsequent nosecones have performed without issue in flight.

On March 26, 2010, the last of 52 production units was shipped from Marshall to Michoud. Forty-four nose cones manufactured at Marshall have flown on shuttle flights and two are installed on ET-122 and ET-138 – scheduled to fly on STS-134 and STS-135, respectively. Six remain at Michoud – four that were damaged there and two spares. Another two shells were made and stored at Marshall.

Sparks is chief of the Nonmetallic Materials Branch in Marshall's Materials and Processes Laboratory.

MARSHALL STAR

Vol. 51/No. 30

Marshall Space Flight Center, Alabama 35812
256-544-0030
http://www.nasa.gov/centers/marshall

The Marshall Star is published every Thursday by the Public and Employee Communications Office at the George C. Marshall Space Flight Center, National Aeronautics and Space Administration. Classified ads must be submitted no later than 4:30 p.m. Thursday to the Marshall Public and Employee Communications Office (CS20), Bldg. 4200, Room 102. Submissions should be written legibly and include the originator's name. Send e-mail submissions to: MSFC-INTERCOM@mail.nasa.gov. The Star does not publish commercial advertising of any kind.

Manager of Public and Employee Communications: Dom Amatore
Editor: Jessica Wallace Eagan

U.S. Government Printing Office 2011-723-031-00094

www.nasa.gov

PRE-SORT STANDARD
Postage & Fees PAID
NASA
Permit No. 298