

VOLUME 5 ISSUE 1 WINTER 2011

Rendezvous

Where today meets tomorrow

End of an Era

T&R Progress Report:

This winter's transition and retirement activities across NASA.

The Meaningful Work We Do:

Shuttle and station are just two components in a much grander scheme.

Moving Forward:

Assembly complete. So what's next for the International Space Station?

Life After Shuttle:

What can we learn from folks who have already transitioned?

From Leadership

From The Editor

Archives

DATA OWNER: Brandi Dean

CURATOR: David Kiss

RESPONSIBLE NASA OFFICIAL: Michael McGuyer

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TRANSITION & Retirement

COMMENTS? QUESTIONS?

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Pictured above: Atlantis touches down on Runway 33 at the Shuttle Landing Facility at Kennedy Space Center just before dawn on Sept. 26, 2006, concluding the STS-115 mission to deliver the P3/P4 integrated truss structure to the International Space Station.

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Pictured above: Discovery touches down at sunset on Runway 15 at the Shuttle Landing Facility at Kennedy Space Center on the shortest day of the year, Dec. 22, 2006, concluding the STS-116 mission to attach the P5 integrated truss structure to the International Space Station.

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Pictured above: Challenger seems to float in the fog over Kennedy Space Center as it moves along Crawlerway to Launch Pad 39A, from which it lifted off on Jan. 24, 1983, on the STS-6 mission.

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Pictured above: Atlantis glides to the runway at the Shuttle Landing Facility at Kennedy Space Center just before noon on Oct. 18, 2002. The STS-112 mission expanded the size of the International Space Station with the addition of the S1 truss segment.

From Leadership

In a sense, our Space Shuttle Program is running true to form even in its last days. We've become accustomed to schedule slippages throughout the history of the program because we value safety above all else and know that there's nothing routine about spaceflight. So, even the sunset of our program is subject to delay — frustrating for some who are eager to move on, but a relief for those who are reluctant to go. Fleeting relief, perhaps, because we can see the finish line from where we stand. But the extra time we've gained with the schedule slippage affords us several opportunities.

First of all, it gives the agency time to better define “next steps” and determine our future course. We all know that the agency is undergoing significant change, after all, and this extra time is actually needed to plan. It's our chance to stop, take a deep breath and refocus on NASA's broader objectives and the mandates of its directorates.

Second, it gives us time to take full advantage of the transition resources created to help our workforce move on. The undeniable fact is that the shuttle will be retired, probably before the end of the summer, and that means many of us won't be able to come in and do the work we've been doing for years. Now's the time to use what's been put into place: the workforce resources, counseling services, management support, and job bulletin boards and centers. It's time for you to get creative and think outside the box about where you can use the skills you honed on the shuttle program.

This may seem like oversimplification, but engineering principles are engineering principles. The opportunities lie in how, when and where they are applied. What programs or projects could benefit from your wealth of experience? Where can your skills take you? What do you like and not like about your job? Then it's time to take the first steps in the direction you want to go. With planning and perhaps a little luck (as in being in the right place at the right time), it's my hope and wish that we keep as much of our shuttle expertise as we can. This is hard-won knowledge and experience, and we should trust it to carry us forward into the future of space exploration.

This is our final issue of *Rendezvous* in magazine form. *Rendezvous* was originally developed to address the issues of shuttle transition and retirement, and how we address such issues is subject to change as well. *Rendezvous* will continue, however, as a website filled with shuttle transition and retirement resources and information and articles similar to what you have read within these pages. We hope this will help us get you more timely, and just plain more, information.

In closing, I'd like to emphasize that although much has changed in the space program, what has not changed, nor will ever change, is the caliber of the people who have worked so hard to make it happen. Programs come and go, but there will always be dreamers and would-be spacefarers who look up and think “Let's go there.”

And there will always be NASA people who have the will and the way to achieve it.



Dorothy Rasco
Manager, Space Shuttle Business Office
SSP T&R Lead
Johnson Space Center

From the Editor

We look both forward and backward in this issue of *Rendezvous*. We look forward with anticipation and excitement about what the future, largely unwritten as yet, promises for human spaceflight and the continued exploration of our cosmos. And we look backward with a sense of bittersweet awe at the long history of the Space Shuttle Program, and the truly amazing achievements of our workforce.

In our "Transition & Retirement Progress Report," you'll note that there are fewer shuttle program closeout activities to report on across the sites, and more testing and milestones met for the International Space Station and the Commercial Orbital Transportation Systems and Cargo Resupply Services projects. There's also the issue of the 2011 budget and what that does or doesn't mean for the Exploration Systems Mission Directorate and the potential cancellation of the Constellation Program — still unresolved as of publication.

In "The Meaningful Work We Do," we learned about the broad scope of engineering and scientific programs and projects currently being worked across the entire agency. Too often, we forget that NASA comprises four mission directorates, two of which are not directly involved in human spaceflight. We hope that this article will help remind you how important NASA's work is in the big picture of improving life on Earth and answering the age-old questions of how our planet came to be, when and how our cosmos was formed and how it's expanding now.

In "Moving Forward: What's next for the International Space Station," we took a look at ongoing station utilization and the role it plays in demonstrating exploration-enabling technology. The station is first and foremost an orbiting space lab, and there is much we can learn from conducting experiments in microgravity about how astronauts, hardware and sensitive instrumentation will fare on long-duration missions. There is also much we can learn on station that will deliver real benefits back on Earth, particularly in the realm of healthcare.

In "Life After Shuttle," *Rendezvous* sat down with three individuals who have all transitioned from their work on the shuttle program. We hope you'll find their stories inspiring as you plot your own path forward.

Finally, "The Shuttle Program: A Tribute in Pictures Mission by Mission" is a commemorative look at the entire program to date. As we all well know, the shuttle program is much more than launching and landing. Our look back celebrates all the people across the country and around the world that made the shuttle program possible. This tribute is for all of you and is designed to be printed out as a keepsake of the program.

Although launch schedules slip and the end date for the shuttle program keeps moving farther to the right, the clock has run out on *Rendezvous* as a quarterly publication. This is our final issue as a shuttle workforce publication, but it's not the end of the *Rendezvous* resource. You'll be able to find timely and important information regarding shuttle program transition and retirement activities and progress on the *Rendezvous* website. So please, if you haven't already, subscribe to *Rendezvous* to receive our e-mails and updates so you can keep reading and learning about T&R news, issues and activities across the agency.

In closing, may your futures be limited only by your imaginations . . .
and all your space-faring dreams come true.

T&R Progress Report

Activities Across NASA

This winter's transition and retirement activities across NASA.



Pictured above: Space shuttle Discovery arrives at Launch Pad 39A after midnight on Sept. 21 to begin launch preparations for its final mission to the International Space Station. This mission will conclude its 28-year career that included such notable missions as the Hubble Space Telescope deployment in April 1990 (STS-31) and the Return to Flight mission in July 2005 (STS-114).

Discovery's Last Ride

Discovery, as it turns out, is destined to have at least two "last rides" out to Launch Pad 39A at Kennedy Space Center. Initially targeted to launch on the STS-133 mission to the International Space Station on Nov. 1, the stack rolled out of the Vehicle Assembly Building on Sept. 20, and arrived at its destination on Sept. 21 to begin preparations for its last mission prior to retirement.

Discovery's Last Ride

Funded to Fly

SpaceX Brings It Home

Stennis Gets Fired Up

Launch Vehicle Studies Candidates Chosen

History in the Making

Robotic Lander Project Passes Test

Freedom Delivers the Last ET

Hitching a Ride

STORRM on the Horizon

DM-2 Rocket Fires

But final missions are not without a certain amount of drama. Roughly a week later, five lightning strikes in the five-mile vicinity of the launch complex caused a flurry of evaluation activities. Although Tropical Depression 16 was forecasted to pass offshore the following day bringing with it the potential for high wind and heavy rain, Discovery remained on the pad, and technicians continued their standard leak checks and pad processing. The shuttle's crew arrived at Kennedy Space Center to conduct launch training two weeks later.

On Oct. 18, just 13 days prior to its targeted launch, technicians discovered a small leak in a propellant line for Discovery's orbital maneuvering system engines. In testing a day later, the leak stopped. However the decision was made to pump out the propellants already inside the tanks and replace the seals at a flange located at the interface where two propellant lines meet.

The seals were replaced and the Flight Readiness Review on Oct. 25 cleared the shuttle for launch as planned Nov. 1, which was scrubbed and reset for the following day, which was scrubbed and reset for Nov. 3, then the 5th, then the 30th, then Dec. 3, then Dec. 17, then Feb. 3 and, as of publication date, Feb. 24. The causes of the slippage were weather delays, leaks detected at the ground umbilical carrier plate and cracks in stringers located on the ribbed intertank portion of the external fuel tank.

Discovery underwent a successful tanking test out at the pad on Dec. 17, after which it was rolled back to the Vehicle Assembly Building to wait until its time to start its last ride out to the pad all over again.



Space shuttle Discovery, begins its rollout from the Vehicle Assembly Building to Launch Pad 39A for mission STS-133.

Funded to Fly (at Least Twice More)

On Dec. 22, President Barack Obama signed into law a short-term appropriations bill that funds the federal government, including NASA, at 2010 spending levels through March 4. Known as a continuing resolution (CR), H.R. 3082 was adopted by the U.S. House of Representatives 193-165 on Dec. 21, 2010. The resolution is a departure from an earlier version drafted and adopted by the House, which would have increased NASA spending by \$186 million over 2010 levels, and provided authority to cancel various Constellation Programs contracts and initiate new programs. Similar language for NASA was included in the Senate's draft omnibus legislation for 2011, however that measure also was not adopted by Congress. Congressional negotiation on the final disposition of the fiscal year 2011 appropriations bills continues.

The CR also provides the Space Shuttle Program with the resources to fly two more missions (STS-133 and STS-134) ...

Because continuing resolutions provide for funding at the same level as the previous year, it calls for NASA to continue funding the Constellation Program. The CR also provides the Space Shuttle Program with the resources to fly two more missions (STS-133 and STS-134) and continue planning and processing flow activities for an additional mission in late June. The agency is currently taking steps to execute contract modifications necessary to fly past the March 31 contract end dates, although some contractor layoffs will occur as initially planned in January.

The agency is currently reviewing H.R. 3082. At present, it does not appear that the measure inhibits the flying of the two manifested shuttle missions, nor the additional shuttle mission tentatively scheduled for early summer.

SpaceX Brings it Home Without a Hitch

SpaceX Corporation successfully tested its Falcon 9 rocket and Dragon capsule combination at Cape Canaveral on Dec. 8, becoming the first private company to safely guide a spacecraft back from Earth's orbit. After spending a little more than three hours in orbital maneuvers, the uncrewed capsule splashed down off the California coast.

It was the first test flight under NASA's Commercial Orbital Transportation Services contract (COTS). The flight was the second for the Falcon 9, a 180-foot-tall, medium-lift booster rocket SpaceX developed in part to service the station.

"This is really an amazing accomplishment for SpaceX," said Alan Lindenmoyer, NASA's Commercial Crew and Cargo program manager. "From all indications, it looks like it was 100 percent successful."

The test is in keeping with NASA's desire to utilize rockets like the Falcon 9 and Orbital Sciences' Taurus II to carry



The SpaceX Falcon 9 with the Dragon capsule attached blasts off the launch pad at Complex 40 in Cape Canaveral to begin a successful test flight.

supplies, experiments and equipment to the space station after the space shuttle fleet is retired. The next Falcon/Dragon launch is slated later this year. The mission could clear the way for a Dragon spacecraft to be sent to the station sometime in the next year, potentially delivering cargo on the flight.



Test firing the AJ26 engine at the E-1 test stand at NASA's Stennis Space Center.

Stennis Gets Fired-Up

NASA's Stennis Space Center in Mississippi recently conducted a successful test firing of the liquid-fuel AJ26 engine that will power the first stage of Orbital Sciences' Taurus II space launch vehicle. The test, which was the first in a series of three firings, lasted 10 seconds and served as a short duration readiness firing to verify AJ26 engine start and shutdown sequences, Stennis' E-1 test stand operations and ground test engine controls.

The NASA-Orbital partnership was formed under the agency's Commercial Orbital Transportation Services joint research and development project. The company is under contract with NASA to provide eight cargo missions to the space station through 2015. In addition to the Orbital partnership, Stennis also conducts testing on Pratt & Whitney Rocketdyne's RS-68 rocket engine.

Launch Vehicle Studies Candidates Chosen

NASA has selected 13 companies for negotiations leading to potential contract awards to conduct systems analysis and trade studies for evaluating heavy-lift launch vehicle system concepts, propulsion technologies and affordability.

The selected companies are:

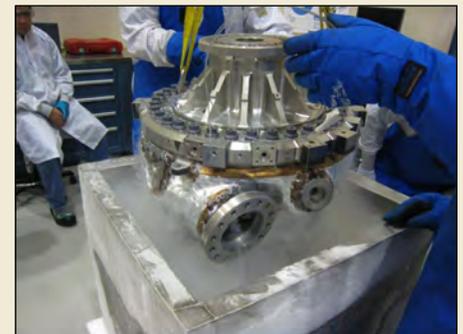
Aerojet General Corp.
Analytical Mechanics Associates
Andrews Space
Alliant Techsystems
The Boeing Co.
Lockheed Martin Corp.
Northrop Grumman Systems Corp.

Orbital Sciences Corp.
Pratt & Whitney Rocketdyne
Science Applications International Corp.
Space Exploration Technologies Corp.
United Launch Alliance
United Space Alliance

The awards total approximately \$7.5 million with a maximum individual contract award of \$625,000. Each company will provide a final report to help lay the groundwork for the transportation system that could launch humans to multiple destinations, including asteroids, the moon and Mars.

History in the Making

Though it is the first new, large, human-rated liquid rocket to be developed in the U.S. since the presidency of Gerald Ford, the J-2X engine has a legacy that stretches back to the Apollo Program. Its predecessor, the J-2, powered the second and third stages of the Saturn V rocket. Today, as the beneficiary of more than 50 years of rocket engine experience, it is an efficient and versatile engine with the ideal thrust and performance characteristics to power the upper stage of a heavy-lift launch vehicle. Appropriately, it is being developed by NASA's Marshall Space Flight Center in Huntsville, Ala., home of the propulsion systems for the Apollo and Space Shuttle Programs.

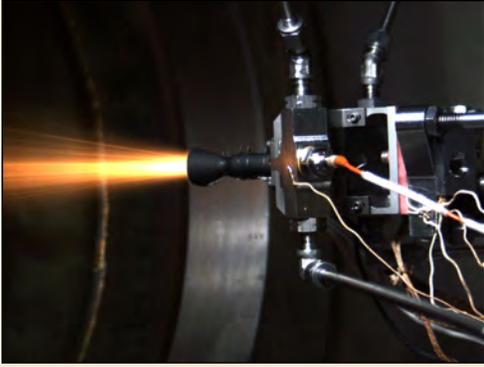


NASA's J-2X rocket engine takes a plunge into a cauldron of liquid nitrogen during the manufacturing process. Key components of the J-2X fuel turbopump were assembled at Pratt & Whitney Rocketdyne's facility in Canoga Park, Calif., at extreme temperatures to ensure the right fit. Credit: Pratt & Whitney Rocketdyne.

Robotic Lander Project Passes the Test

Marshall Space Flight Center recently collaborated with White Sands Test Facility and Pratt & Whitney Rocketdyne to complete a series of thruster tests at the White Sands' test facility. The tests will aid in maneuvering and landing the next generation of robotic lunar landers that could be used to explore the moon's surface and other celestial bodies.

The Robotic Lunar Lander Development Project at Marshall performed the hot-fire tests on two



The Divert Attitude Control System thruster is tested at NASA's White Sands Test Facility.

high thrust-to-weight thrusters – a 100-pound-class for lunar descent and a 5-pound-class for attitude control. A lunar mission profile was used during the test of the miniaturized thrusters to assess the capability of these thruster technologies for possible use on future NASA spacecraft.

During tests of the 100-pound thruster, the Divert Attitude Control System developed by the U.S. Missile Defense Agency of the Department of Defense fired under vacuum conditions to simulate operation in a space environment. The tests recreated the lander mission profile and operation scenarios. The objective for the 5-pound-class thruster was similar, with an additional emphasis on the thruster heating assessment.

The test program fully accomplished its objectives, including evaluation of combustion stability, engine efficiency, and the ability of the thruster to perform the mission profile and a long-duration, steady-state burn at full power. The test results will allow the Robotic Lander Project to move forward with robotic lander designs using advanced propulsion technologies.

Freedom Delivers the Last External Fuel Tank

Freedom Star, one of NASA's solid rocket booster retrieval ships, recently delivered the Space Shuttle Program's last external fuel tank to Kennedy Space Center. The tank, ET-122, traveled 900 miles from NASA's Michoud Assembly Facility in New Orleans aboard the Pegasus Barge. It will eventually be attached to space shuttle Endeavour for the STS-134 mission to the International Space Station. With the delivery of the tank, Lockheed Martin announced the decision to close its external tank plant after 37 years and 136 tanks constructed.



One of NASA's solid rocket booster retrieval ships, Freedom Star, tugs ET-122, the Space Shuttle Program's last external fuel tank, toward NASA's Kennedy Space Center.

Hitching a Ride

Two unpressurized orbital replacement units, or spare parts, bound for the International Space Station are scheduled for delivery by a launch vehicle other than the space shuttle. The spare parts are traveling more than 7,500 miles by land, air and sea to arrive at their final processing and launch destination in Tanegashima, Japan.

"We've never done this before," said Jose Nunez, the NASA mission manager at Kennedy Space Center. "This is a whole new set of firsts that we've embarked on for NASA and Kennedy Space Center."

The spare parts are a flex hose rotary coupler and a cargo transportation container, which is basically a box containing five smaller spare parts. They were installed in a Japanese H-II Transfer Vehicle (HTV-2) and launched to the International Space Station aboard a Japanese H-IIB rocket on Jan. 21.

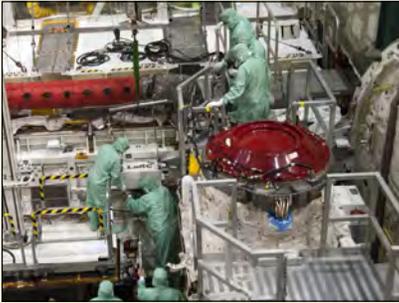
The station's Expedition 26 crew members will use the Canadarm 2 to capture the HTV-2 and guide it to the Nadir port on the station's Harmony module. The spare parts will then be moved first to the Japanese Exposed Facility and then to the Express Logistics Carrier-4, with the help of the Canadian Special Purpose Dexterous Manipulator - also known as Dextre - another first.



In the Space Station Processing Facility at KSC, the cargo transportation container is installed in a shipping container to prepare for its journey to Japan and then the space station.

STORRM on the Horizon

Though STS-134 is scheduled to be one of the final space shuttle flights, the docking and rendezvous technology it is taking along will just be making its debut. Known as the Sensor Test for Orion Relative Navigation Risk Mitigation, the STORRM system was designed for use on the Orion capsule. It was installed Aug. 10, inside Endeavour's payload bay, where it will fly as an in-flight experiment.



The Avionics Enclosure Assembly is moved into its flight location in Endeavour's payload bay for its upcoming mission, STS-134.

STORRM includes a Visual Navigation Sensor (VNS), as well as an advanced docking camera. The VNS relies on a light-based remote sensing technology called lidar to provide extremely accurate data, while the docking camera offers high-resolution docking imagery.

When the STORRM's two hardware components - the Sensor Enclosure Assembly and the Avionics Enclosure Assembly (AEA) - were lowered into place in Endeavour's payload bay, an unusually large crowd of enthusiastic agency and contractor representatives were on hand.

"I'd have to say this is the most people I've ever seen come for a payload installation," said Shelly Ford, NASA's Vehicle Manager for Endeavour. "It's exciting that Endeavour will be contributing to the technology development for our future space program."

According to Deputy Project Manager Rick Walker, visiting from NASA's Langley Research Center in Virginia, the assembly's location in the payload bay is due to large volumes of high-speed data the hardware will have to digest. Placing it in the bay, however, resulted in the need for radiation-tolerant memory. The team succeeded by using a blend of commercial and Langley-developed technologies, which allowed them to complete the work in nearly half the time it normally would take.

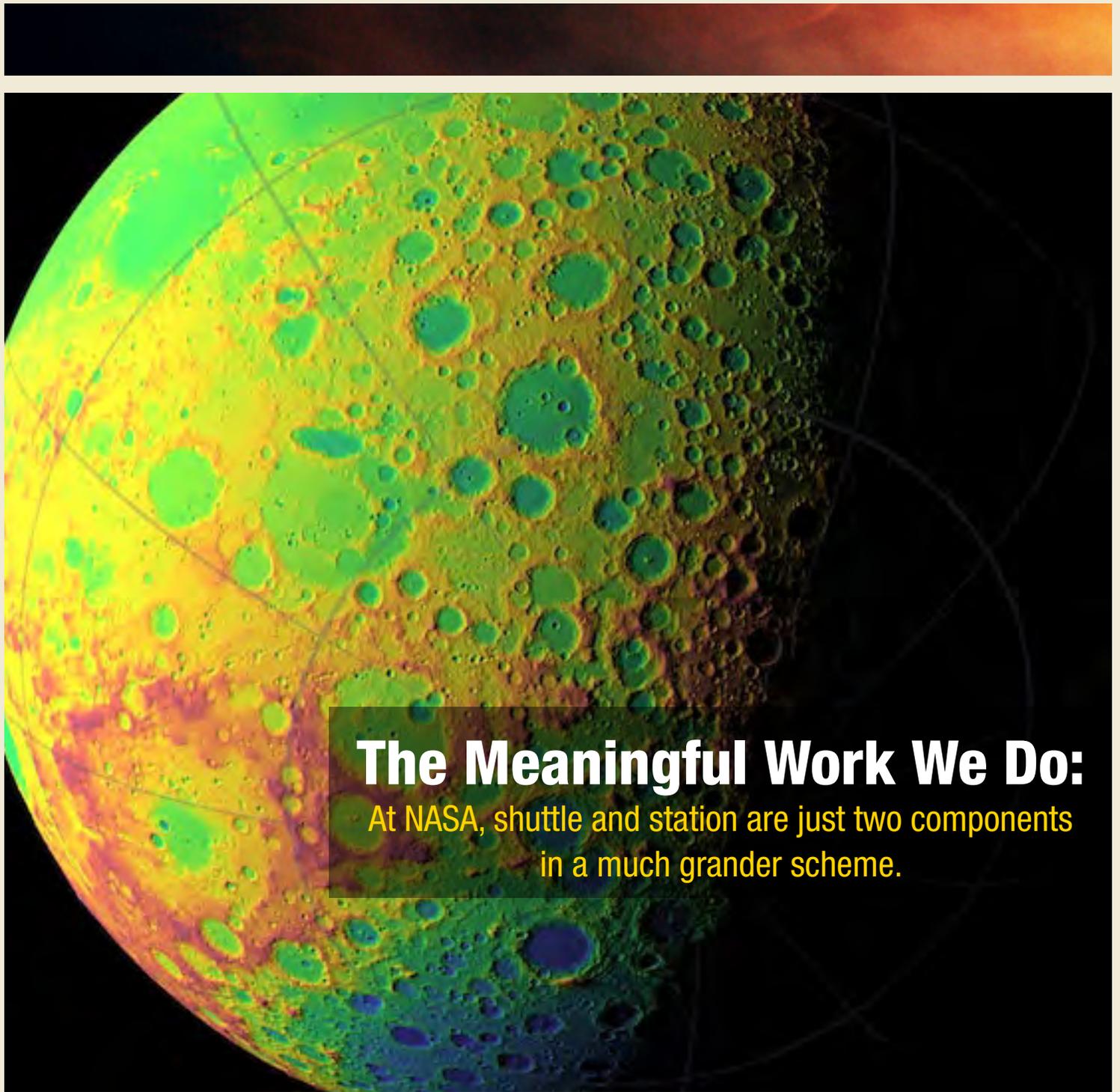
"This was done in 14 months - a pretty quick turnaround," Walker said after the AEA was bolted into place. With the testing and checkout of the STORRM payload completed in August, this STORRM is ready for flight.

DM-2 Rocket Fires

NASA and Alliant Techsystems Aerospace Systems successfully completed a two-minute, full-scale test of Development Motor-2 (DM-2), the largest and most powerful solid rocket motor designed for flight. Although similar to the solid rocket boosters that help power the space shuttle to orbit, this five-segment development motor includes several upgrades and technology improvements implemented by NASA and ATK engineers. Upgrades include the addition of a fifth segment, a larger nozzle throat and upgraded insulation and liner. The motor cases are flight-proven hardware used on shuttle launches for more than three decades. The motor is potentially transferable to heavy-lift launch vehicle designs.



Ignition of Development Motor-2 (DM-2) during testing. DM-2 is the most powerful solid rocket motor designed for flight.



The Meaningful Work We Do:

**At NASA, shuttle and station are just two components
in a much grander scheme.**

Picture above: NASA's Lunar Reconnaissance Orbiter is helping to create an unprecedented topographic map of the moon.

To many of us in the Space Shuttle Program, it seems like our own personal space program is coming to a close. The work that delivers such an overwhelming sense of accomplishment, teamwork, commitment and pride ends later this year. Once the wheels stop on our final mission, we're done.

But that's not really the case. And it's certainly not the end of the American space program.

What we tend to forget is that NASA is not just shuttle and station. Even within the realm of the Space Operations Mission Directorate, there's a lot more going on at NASA. There are also the Aeronautics Research, Exploration Systems and Science Mission Directorates with activities, research programs and development projects that answer NASA's overarching mission — to improve life here, to extend life to there, to find life beyond.

All the other programs, besides the International Space Station, are unmanned exploratory missions designed to help us learn more about the history, nature and potential of our solar system and the universe beyond, or research and development programs intended to positively impact the aeronautics and commercial aviation industries for the benefit of the American people. NASA's name is, after all, the National Aeronautics and Space Administration. And within these four directorates, their programs and projects are all meaningful.

Aeronautics Research Mission Directorate: Greener skies ahead

Improving how we move around within the Earth's atmosphere and how we sustain our "close-in" flight environment are the overarching objectives of the ARMD. Tom Irvine, deputy associate administrator, explained that his mission directorate's R&D objectives and activities fall into three key areas of endeavor: air traffic management, aviation safety and green aviation. Most of the work is conducted in the research center realms of Langley, Glenn, Ames and Dryden.

The **Airspace Systems Program** is tasked with researching and developing technology solutions for the Federal Aviation Administration's next generation air traffic management system. This rather broad objective is broken into four project areas: 1) Develop a better system that will accommodate the projected growth in air traffic; 2) Help make it less congested and more efficient; 3) Aid the flying public with reduced door-step-to-destination trip durations and a cleaner flying environment (skies and airports); and 4) Meet our civil aviation, national defense and homeland security needs. NASA is not alone in this effort to help keep pace in a rapidly evolving scientific and technical environment. The NASA ARMD's Airspace Systems Program team is in good company thanks to the creation of the FAA's Joint Development and Planning Office (JDPO) enacted by the Vision 100 Century of Aviation Reauthorization Act (Public Law 108-176). Joining NASA's team in the JDPO are representatives from the Department of Transportation, the Department of Defense, the Department of Commerce and Homeland Security.

Another of ARMD's programs is taking a new approach to aviation safety, Irvine said. Until now, the field has been primarily a backward-looking science. In other words, once an incident has occurred, an investigation looks into its causes and recommendations are submitted to help avoid future incidents of a similar nature. The **Aviation Safety Program**, in contrast, is all about proactive risk mitigation in a flight environment filled with airframes of all ages, design, technology, purpose and capacity.

"Our program is about looking ahead to figure out what we can do to anticipate the causes of incidents and prevent them," Irvine explained. This includes understanding the durability and aging characteristics of metals and advanced composites, predicting and managing the overall health of aircraft in flight and lessening the effects of aircraft upset and loss of control.

Last, but by no means least, the Aviation Safety Program is also working on the Integrated Intelligent Flight Deck Project, providing the vision, design methods and analysis tools for integrating human safety factors into the flight decks of the future.

The **Integrated Systems Research Program** is focused on maturing and integrating technologies into next generation flight vehicle systems and subsystems to address several aviation challenges, including energy consumption and environmental impact. The program's researchers explore, assess and demonstrate the benefits of technologies in a relevant environment to accelerate their transfer to the aviation community. Their key project is the Environmentally Responsible Aviation Project known more familiarly as "green aviation." Its primary goal is to select and qualify vehicle concepts and technologies that will simultaneously

ARMD Programs

- Airspace Systems Program (air traffic management)
- Aviation Safety Program
- Integrated Systems Research Program (technology integration, green aviation)
- Fundamental Aeronautics Program
- Aeronautics Test Program



Prototype testing of a new, quieter, more fuel-efficient aircraft design is taking place inside a historic wind tunnel at NASA's Langley Research Center in Hampton, Va.

reduce fuel consumption, noise and emissions.

The **Fundamental Aeronautics Program** is the one ARMD program that crosses the line between atmospheric aviation and spaceflight. Its objectives and activities focus on the development of technologies and tools to enable revolutionary changes for vehicles across all flight regimes, from subsonic to hypersonic. One of its more future-facing projects is the Hypersonics Project that includes work on Reliable Airbreathing Launch Vehicles (RALV) and the Planetary Atmospheric Entry System (PAES). RALV involves the development of air-breathing propulsion technology and PAES enables the safe and precise landing of large payloads on the surface of Mars.

Lastly, under the auspices of the **Aeronautics Test Program**, the ARMD is responsible for the preservation and protection of the wide array of aerospace and aviation test facilities that are situated at the agency's four research centers.



Tests to help develop technologies for future high-altitude, long-endurance unmanned aircrafts are taking place in the Transonic Dynamics unnel at NASA's langley Research Center.

Center	Facilities
Ames Research Center	Wind tunnels
Dryden Flight Research Center	Test bed aircraft, support aircraft, test range, simulation and flight load labs
Glenn Research Center	Wind tunnels, icing research tunnel, propulsion testing facilities
Langley Research Center	Wind tunnels, spin tunnel, aerothermodynamics testing facility

Obviously, R&D work that runs the gamut from air traffic management and green aviation to advanced flight systems relies on a wide range of engineering disciplines — mechanical, structures and materials, aerodynamics, thermodynamics, aero sciences, chemical (fuels) and electrical, to name a few. And it relies on a level of commitment similar to the one you find running through the shuttle program. Irvine maintains that the people in aeronautics research are just as passionate about what they do as shuttle and station folks, but with a difference: What fires them up is not the concept of space and space exploration, but the technology necessary to take us there.

"People in the space program love it because it's truly their life's calling. People in research love it because they love technology," Irvine concluded.

**Science Mission Directorate:
Answering the big questions**



Technicians at NASA's Marshall Space Flight Center's X-ray & Cryogenic Facility conduct a series of cryogenic tests on six James Webb Space Telescope beryllium mirror segments.

How did the planets originate? How does the universe work? How and why are the Earth's climate and environment changing? How does the sun vary and how does that impact Earth? How did life come to be? Are we alone in the universe?

These are profound, age-old questions and NASA's Science Mission Directorate (SMD) seeks to answer them because NASA, with its access to space, is uniquely positioned and qualified to do so. Paul Hertz, SMD's Chief Scientist, explained that although the pursuit of science is a broad endeavor that involves many thousands of scientists, engineers and other experts around the world and many, many missions to cover the breadth of science, everyone is pretty much working toward the same goal — to answer those big-picture questions.

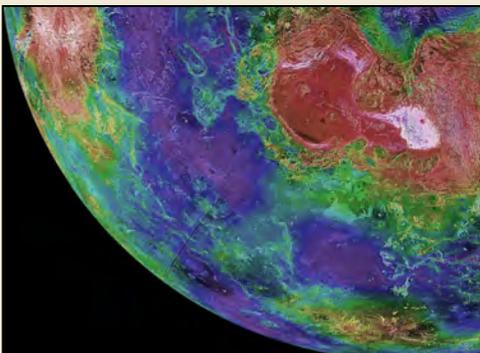
The Science Mission Directorate divides its research into four major categories that extend out from the Earth in concentric rings. They are, starting from the farthest out and working inward, Astrophysics, Planetary Science, Heliophysics and Earth System Science.

Astrophysics strives to observe the universe and explain the Big Bang, dark energy and dark matter, stars, our own galaxy, black holes and planets around other stars (exoplanets). It is the domain of the agency's Great Observatories currently in orbit — the Hubble Space Telescope, the Chandra X-ray Observatory and the Spitzer Space Telescope — which look closely at distant stars and galaxies to understand how they work and discover the origins, structure and evolution of our cosmos. The Kepler mission is looking for Earth-sized planets that orbit other stars to try to determine how common Earth-like planets — planets that may be capable of supporting life — are in our galaxy. Currently in development, the James Webb Space Telescope will have a mirror seven times larger than Hubble and will be launched in the largest rocket the European Space Agency has to offer. A key difference between this telescope and the others is that the James Webb will orbit our sun, not Earth, at a distance of a million miles away, in order to observe the first stars and galaxies in the universe.



A Hubble image of Red Supergiant Star V838 Monocerotis.

As its name would suggest, **Planetary Science** focuses a bit closer in on the planets in our own solar system — the rocky inner solar system planets of Mercury, Venus, Earth and Mars; the gas giants of the outer solar system — Jupiter, Saturn, Uranus and Neptune; and Small Bodies including asteroids, comets, and the distant objects in the Kuiper Belt and the Oort Cloud, which are actually remnants of our solar system's formation.



More than decade of radar investigations culminated in this hemispheric view of Venus.

"We're trying to understand how we got here, and whether there's life elsewhere in the universe," Hertz explained. "And the closest place to look is elsewhere in our solar system."

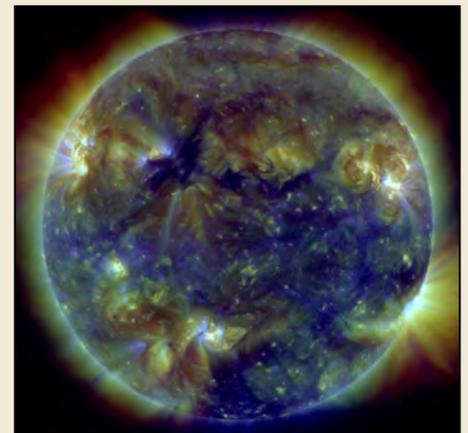
Those are the key objectives of the Mars program and the missions in orbit around Saturn and soon Mercury, all of which are run out of the Jet Propulsion Laboratory (JPL) in California and the Applied Physics Laboratory (APL) in Maryland. Missions currently under consideration or in the planning phase might include landing on the surface of an asteroid or the moon to bring back samples for study, or on Venus. This would require orbiting other planets and then operating in their atmospheres and mastering the aerodynamics of re-entering Earth's — all technical skills and capabilities originally developed for manned spaceflight programs, including the shuttle program.

But the next big Mars mission promises to yield a treasure trove of information. Roughly the size of a small compact car, the Mars Science Laboratory is scheduled to launch this year and will run 24/7 on nuclear power. Its onboard organic chemistry laboratory will be able to perform extremely sensitive chemical testing on samples on the surface of Mars. Too big and heavy to survive a parachute hard-landing, the mobile laboratory will be lowered to the surface of the planet from its carrier vehicle with a sky crane — science fiction-like technology developed by the folks at JPL.

"It takes the very best technical experts that the nation has to offer to do something like this a hundred million miles away," Hertz stated.

The SMD's third category of study is **Heliophysics** — the study of the sun and its influence on the Earth and the remainder of the solar system. One mission, known as STEREO, features two identical spacecraft in chasing orbits around the sun, one ahead of the Earth and one behind. The spacecraft observe the sun from two different angles to obtain stereoscopic views of its surface conditions. This allows scientists to study solar flares or corona mass ejections in 3D and record how they change as they move away from the sun and how they affect the Earth and the space-based infrastructures that are sensitive to solar radiation, such as satellites for communications, security, data transfer and weather forecasting.

The Solar Dynamics Observatory (SDO), NASA's new heliophysics flagship mission which launched earlier this year, is parked in a geostationary orbit in a position that is never in Earth's shadow so that it can capture continuous high definition movies of the sun in eight different colors. The SDO is currently beaming down voluminous amounts of data, filling up hundreds of CDs per day and enabling scientists to watch detailed behaviors of the sun to try to understand what causes



An ultraviolet snapshot of our Sun from the Solar Dynamics Observatory (SDO).

its massive energy releases.

Another mission in development, the Radiation Belt Storm Probes, features a pair of satellites that will fly together through the Earth's atmosphere to record the planet's magnetic field's and radiation belt's response to the sun. Through the study of the sun, the heliosphere and its associated planetary environments, we hope to eventually come to understand it as a single connected system and better grasp the fundamental physical processes of space plasma systems.

"When we start going beyond low Earth orbit, out to an asteroid or on to Mars, we'll need to protect our voyagers from cosmic and solar radiation," Hertz explained. "Our study of heliophysics will help us develop space weather predictive capabilities to ensure the safety of our astronaut explorers once they leave the protection of the Earth's magnetic field."



This satellite image of Alaska's Susitna Glacier combines infrared, red and green wavelengths to form a false-color image.

Earth System Science is the fourth area of science under the Science Mission Directorate's purview. Based on scientific understanding of our climate and Earth as a system, we can help impact policy choices by providing data to the policy makers on the Hill and in other agencies. As recently as 20 years ago, Earth science was conducted by geologists studying rocks, oceanographers studying the oceans and atmospheric chemists studying the atmosphere. Thanks in part to NASA's research and science missions, we now know that these are not three isolated areas of study, but that they are, in fact, all part of the Earth System.

Earth System Science missions are, for the most part, multi-purposed. Aura, Aqua and Terra are large satellites that are recording images with moderate imaging systems — or MODIS — cameras and measuring the chemistry of the atmosphere and the solar radiation that the Earth is absorbing. The ICESat (Ice, Cloud and land Elevation Satellite) and ICESat II missions (the latter of which is in development) use lasers to measure the height of the ice caps at our poles as a method of tracking global warming. Specialized missions currently in planning and development will measure both carbon dioxide and water evaporation in the Earth's atmosphere to better understand climate change and measure changes in the Earth's surface to aid land-use policy makers. In effect, Earth Systems Science helps identify the parts of the system that need to be better measured.

These are all space missions that require specific technical capabilities and expertise — communications, thermal systems, propulsion, power systems, entry, descent and landing. They call for all of the same technical skills that went into building and operating both the shuttle and the station.

Exploration Systems Mission Directorate: Beyond low Earth orbit

The Exploration Systems Mission Directorate remains focused on developing and managing the capabilities and technologies that NASA will need for future humans exploration missions beyond low Earth orbit. The primary current work of ESMD is to align its resources and mission priorities with the direction provided by Congress in the Authorization Act of 2010 and signed into law by the president. Although NASA will be operating under a continuing resolution through March 4 (at least), the NASA Authorization Act of 2010 does provide enough information for ESMD to broadly prepare plans for forward work.

As part of the agency's ongoing integrated architecture analysis and program planning efforts for human spaceflight, a Human Exploration Framework Team (HEFT) was chartered to provide decision packages to Agency leadership in order for them to make strategic and technical decisions regarding NASA's future human spaceflight architecture. The chosen capability-driven framework approach is a flexible strategy that opens multiple potential destinations throughout the solar system — including the moon, near Earth asteroids, and Mars as the horizon destination — and is enabled by evolving capabilities, budget allocations and national priorities.

It is within the capability-driven framework approach that ESMD has created study teams to address top-level affordability, cost, performance, schedule, technology and partnership considerations, while emphasizing an early focus on developing the "Big Four": 1) A human-rated **Space Launch System**; 2) A **Multi-Purpose Crew Vehicle**; 3) **Commercial Crew and Cargo Services** to the International Space Station (CCDev and COTS); and 4) **Mission-Focused Technologies**. Leveraging this base,



LRO and LCROSS are united after years of independent development in different facilities.

consistent with law and policy, NASA's capability-driven framework captures the short-, mid-, and long-term plans for human space exploration, which include increased interagency, international and commercial cooperation for the benefit of the nation, while yielding improved affordability, sustainability and flexibility.

In addition to the "big four" mentioned above, ESMD continues to invest in the Advanced Capabilities Division (ACD), which provides the knowledge, technology and innovation that will enable current and future exploration missions. ACD is composed of three major programs: the **Lunar Precursor Robotic Program**, the **Human Research Program**, and the **Exploration Technology Development Program**. These programs and their projects provide knowledge as a result of ground-based research and technology development, research conducted in space and observations from robotic flight missions.

Space Operations Mission Directorate: Enabling missions of all kinds

What most people don't realize is that human spaceflight operations is only one of many programs under the umbrella of the Space Operations Mission Directorate.

"Our mission is to enable NASA missions," said Lynn Cline, deputy associate administrator for SOMD. "We provide access to orbit. We provide platforms in orbit. And we get the data back and forth. A lot of people don't realize all the other things we do."

In fact, the Space Shuttle Program is only one of five different programs managed by SOMD. There are also Launch Services, the Rocket Propulsion Test Program, Space Communications and Navigation and the International Space Station Program. All of them have one thing in common — they're all about spaceflight. They're responsible for launching spacecraft, communicating with and tracking them, delivering goods to the space station (via shuttle), etc. Anything that has anything to do with putting something in low Earth orbit is the responsibility of SOMD.



An early shuttle launch from KSC.

The **Launch Services Program** operates primarily out of Cape Canaveral Air Force Station in Florida. The program's primary customer is the Science Mission Directorate. However, they also work for other parts of NASA — launching TDRS satellites for space ops, and the Lunar Reconnaissance Orbiter for the Exploration Science Mission Directorate, to name a few. These launch services are purchased from commercial companies such as United Launch Alliance and Orbital Space Corporation, among others. Occasionally, launch services are provided for non-NASA customers, such as the Department of Defense or the National Oceanic and Atmospheric Administration. The program also provides mission assurance for all commercial launch services required for robotics missions. The Launch Service Program possesses engineering expertise, technical knowledge and working experience with a variety of expendable launch vehicles spanning the small, medium, intermediate and large classes — from the Pegasus and Taurus, up to the expendable launch vehicles, Atlas V and Delta IV.

The **Rocket Propulsion Test Program** provides the core capability needed to test the space shuttle main engines. With test stands at Stennis Space Center, Marshall Space Flight Center, Glenn Research Center and White Sands Test Facility (for altitude testing), the program can perform just about any propulsion testing necessary on any engine. The program also performs engine tests for non-NASA customers, both commercial and military.

The **Space Communication and Navigation Program**, or SCan, coordinates the multiple networks that include all the ground support networks and network support functions that provide for and enable the transmission of mission data for all of NASA's missions. The program is largely managed out of Goddard Space Flight Center with Ames, Glenn, JPL, Johnson, Kennedy and Marshall participating.



SSME test at Stennis' A-1 Test Stand.

SCaN Project	Objective
Deep Space Network	To maintain the link between spacecraft and the Earth.
Space Network	To provide TDRS coverage for spacecraft, satellites and expendable launch vehicles.
Near Earth Network	To provide services to orbital spacecraft and the space shuttle (including pre-flight, launch, on-orbit, landing and post-flight activities).
Tracking and Data Relay Satellite System	To provide in-flight communications with spacecraft operating in low Earth orbit via eight satellites.
Systems Planning	To develop a communications and navigation architecture to support exploration and science programs through 2030.
Technology	To predict the needs of future communications missions to advance performance and reduce costs.
Data Standards	To pursue the implementation of national and international space data standards in order to improve interoperability.
Agency Spectrum Management	To ensure the availability and allocation of the required radio frequency spectrum to support the operation of navigation systems, space- and ground-based radio transmission and mission sensor operations.
Spectrum Environment	To mitigate frequency and device interferences that affect the radio frequency spectrum.
Search & Rescue	To coordinate with the Distress Alerting Satellite System, and to improve distress alert and location capability.

Aside from overseeing the Space Shuttle Program, the **Human Spaceflight Operations Program** also covers flight crew operations, including the astronaut corps and their aircraft and training, as well as all crew health and safety activities. Finally, there is the International Space Station Program, now moving from the assembly phase into the operations and utilization phase.

Moving Forward



**Assembly complete.
So what's next for
the International
Space Station?**

It's taken us and our international partners 26 expeditions, 34 space shuttle missions and 146 spacewalks to build the International Space Station. And now that we've achieved "assembly complete," it's time to turn our attention to making sure that this \$60 billion asset is productive in the next decade.

Picture above: In the cupola of the International Space Station, astronaut Tracy Caldwell Dyson gazes down at Earth. This image was captured by a member of the Expedition 24 crew on Nov. 15.

Tactically, this requires that we look at the station's mission from two perspectives. First, what are NASA's mission requirements and mission-driven needs for the space station? And second, what are our nation's requirements and uses for this orbiting laboratory?

From the beginning, one of several overarching strategic objectives of the International Space Station was to stimulate economic growth. In other words, open up a new economy in low Earth orbit with the International Space Station positioned as an orbiting catalyst. Presumably, this new economy would be centered on breakthrough scientific discovery, evolving technology demonstration and testing of critical systems.



The brightness of the sun shines on the Russian section of the orbital outpost as seen by the STS-129 crew.

NASA's needs dovetail neatly with the broad space-faring objectives initially advanced in early 2004 in the Vision for Space Exploration, and later refined and restated by President Obama in his 2011 budget for NASA. The agency's objectives are to advance scientific research that will help astronauts survive and thrive on the longer duration missions; study our own home planet, as well as the cosmos around us; and advance spacecraft technology to the next generation.

Our nation's requirements of the space station, on the other hand, come from government agencies other than NASA. This is because the space station's designation as a U.S. National Laboratory fits an inward-facing exploration format that leads to discovery that, in turn, will lead to breakthrough development and innovation on Earth.

Station as an orbiting technology test bed

The station's role as technology test bed platform is not new. Jason Crusan, chief technologist for the Space Operations Mission Directorate, explained that there are already a certain number of technology demonstrations going on in the current program. But with the 2010 Authorization Act, the agency and the program now have additional opportunities to evolve key technologies and a decade-wide window in which to operate.

"We've been looking at how to use the vehicle itself, as well as at the long-term operations of all its subsystems, to advance those technologies and increase our understanding of how these integrated systems will perform in microgravity and over time," Crusan said. "How do we continuously tweak, update and prove these systems to not only increase performance, but to also increase reliability as we go forward?"

“How do we continuously tweak, update and prove these systems to not only increase performance, but to also increase reliability as we go forward?”

Those are the critical factors. Increased performance in space usually means getting more out of less - more power, more upmass, more breathable air, more consumable water, etc. - in order to ensure the health, safety and effectiveness of astronauts on lengthy expeditions to the station. And of course, increased reliability is critical to the success of long duration space missions. Imagine suffering the failure of a critical system on the surface of Mars, where it would take months to obtain replacement parts.

Examples from the current and planned batch of on-station technology demonstration projects and scientific missions include:

- The Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES);
- The Robonaut 2 advanced dexterous humanoid robot to be delivered to station on STS-133;
- The Alpha Magnetic Spectrometer (or AMS-02), an anti- and dark matter detector to be delivered to station on STS-134;
- The integration and testing of the international low impact docking system standards that will be known as the NASA docking system;
- The continually evolving environmental control and life support systems;
- The famed COLBERT - or T2 - treadmill, both an exercise countermeasure device and a research device that will help collect the data needed to look at and evaluate the mechanisms and forces at work in microgravity that cause physical deconditioning of astronauts during long duration missions.

Enthusiastic response, intriguing potential

Crusan also emphasized that the station provides a second kind of test bed that is almost as important to the future of space exploration - an acquisition test bed.

"We're looking at the models we use to acquire the elements and components we need for ISS operation, with an eye to developing more commercial and more efficient acquisition models than our normal cost-plus contracts," Crusan explained.

The example he cited was the Sabatier water production system hardware. In this case, the technology of the system was well understood, so could commercially acquired services prove reliable enough for on-orbit operations? They negotiated with Hamilton-Sundstrand for a service-based contract similar to the kind of commercial contracts commonly applied elsewhere in the commercial sector.

"These commercial models require us to think differently about how we acquire and prove the technology, systems and subsystems needed to operate station," Crusan said. "And we think that developing alternative acquisition models will serve us well in the future."

**... the station is actually an excellent platform
to test subsystem and component-level
technologies without having to
fly (at great expense) an entire system.**

Crusan makes the point that the station is actually an excellent platform to test subsystem and component-level technologies without having to fly (at great expense) an entire system. This means, in effect, that reconfiguration testing of subsystems and components could be accomplished in an iterative fashion much more efficiently and at a much lower cost.

So just how exciting is this notion of station as a test bed? Crusan reported that when the call-for-entries for advanced technology concepts worthy of testing on the space station went out to the agency's flight and research centers, more than 80 different concepts were submitted from all over the country. The entries were narrowed down to a pool of 30 projects considered both intriguing and feasible.

"We're still in the final stages of evaluating some of the project recommendations from the Exploration Systems Mission Directorate, the Science Mission Directorate and the Office of the Chief Technologist," Crusan explained.

Once the final selections are made, pending appropriations outcomes, the Mission Directorates will move forward on concepts that range from small, sub-scaled elements that attach to existing station hardware, to large, modular demos and advanced concepts such as electric propulsion and inflatable habitats.

Adding to our base of knowledge and experience

The biomedical science and research that will be accomplished in microgravity on the station promises to have far-reaching impacts in such earthbound realms as preventive medicine, food safety, nanotechnology, etc. Full utilization of the space station, however, includes the technology demonstrations that will encourage and enable future space exploration.

Consider these points. We've already learned how to construct a space vehicle and a critical research asset in low Earth orbit. And we've learned how to work and live in space for increasingly long durations. Both of these are necessary for the success of any space exploration program. Continued utilization of the space station will require that we develop, prove and test technology to increase our international partners' access to the station's labs, develop alternative ways to live safely in space without requiring costly upmass capability and work more efficiently in space through the use of non-human "helpers," i.e. sophisticated robotics.

At present, a number of technology demonstration projects address these requirements. The International Docking System Standard, or IDSS, was developed to ensure that any space agency partner building a spacecraft with the intention of docking at the station would have a common berthing interface. Skip Hatfield, NASA's project lead for the NASA Docking System (NDS), explained that two systems will eventually be installed on station. One will go on the



Astronaut Michael Good blends in with the station while working on the installation of the two new batteries for the B side of the port 6 solar array during the third and final spacewalk of mission STS-132.

forward Harmony port, the second on its zenith. And all new vehicles visiting the space station will be required to use them.

To date, the NDS prototype has been developed through system requirements. The next step will be to build the docking system itself and develop a common docking adapter (which will replace the pressurized mating adapters) to launch to station. This universal docking system promises even greater utilization of the space station by enabling the exchange of crew and cargo from any partner agency and the assembly of even larger spacecraft on orbit.

"Since we'll have the same kind of structural capabilities as we currently have with the Russian system (the androgynous peripheral attach system or APAS) holding the entire space station together, we'll be able to use this docking system as a foundation for building larger elements," Hatfield explained.

If you think of the connectors and hubs in a Tinkertoy® set, you've got the basic idea.



Concept art of NASA's Low Impact Docking System.

Testing surface habitat concepts - on orbit

With the probable cancellation of the Constellation Program, the Lunar Surface Systems project, now renamed the Exploration Mission Systems Office, has set its sights for a much more distant objective: Mars. In fact, according to Matt Leonard of the EMS office, they've just kicked off a large effort with the station program and the Constellation operations and test integration office to look at how lunar surface architecture could be migrated to a Mars mission, and what pieces of the architecture should be tested at the space station. Doing so, Leonard explained, entails much more than structural testing.

"We're looking at long duration zero G exposure, because on a Mars mission you'll have at least six months of it," Leonard said. "Then you'll have operations to do once you arrive."

So they're looking at how that long transit will decondition the crew, how productive they'll be and how long they'll need to recover before they can really start exploration on the surface. They're also looking at the psychological impacts of such long periods of isolation with a 20-minute delay in communications with Earth.

**“We're thinking about actually
implementing the delay on station
to simulate a Mars transit mission ... ”**

"We're thinking about actually implementing the delay on station to simulate a Mars transit mission to see how they'd interact with ground control and how they'd adapt," Leonard elaborated.

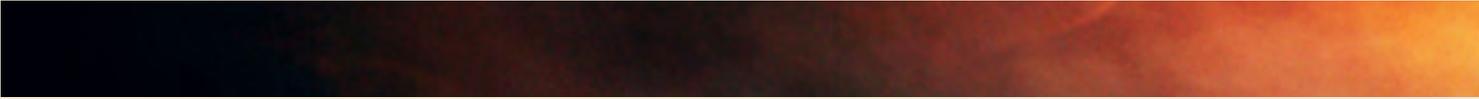
Also, since space station systems aren't as autonomous as Mars mission systems would need to be, the EMS office is looking at using smarter systems on station to lessen the amount of ground interaction required for spacecraft operations.

Evolving ECLSS

With the station's assembly complete, NASA now has the ability to further evolve systems that are critical for spaceflight, such as environmental control and life support systems (ECLSS). According to Mike Raftery, Boeing's deputy program manager for the International Space Station, the success of future space exploration could hinge on the capability of an evolved ECLSS.

"If you step back and look at the space station, the ECLSS systems turn out to be the really hard stuff," Raftery explained. "It's clear that we need to make significant improvements in our ability to provide life support if we're going to go to Mars. In fact, if you stack up all the really important technologies that are needed for exploration, ECLSS needs to be right up there at the top."

ECLSS is a complicated system, vastly impacted by the differences between Earth's gravitational field and the station's microgravity environment, and the program is trying to advance the state of the life-support art as rapidly as possible. This was an area of considerable interest and discussion at a recent American Astronomical Society conference dedicated to ongoing utilization of the space station and attended by most of the key players in the station's future.



**... when system and subsystems are built on
the ground, they will behave differently in space.**

Part of the issue, Raftery explained, is that when systems and subsystems are built on the ground, they will behave differently in space. But when dealing with life support, other variables come into play: How do the astronaut's own biological systems behave differently in space; and how will they interact with the evolved life support systems — none of which can be effectively tested in an environment where gravity is a constant.

"We just can't duplicate the microgravity operational environment on Earth, so that means that in-space testing is critical for these systems," Raftery said. "And are we really confident that if we just start over with a new ECLSS concept, we're going to get it right the first time and use it for potential Mars missions?"

Raftery's point underscores just how perfect the station is for the testing of such critically important systems. And he includes the inflatable habitat module in his list of station-based technology demonstrations.

"The idea would be to build an inflatable module on the station to use as an ECLSS test bed where we could close the hatch and operate it with the crew in a weightless environment for a long period of time," he said. "We'd test those systems, make sure they're working properly, find the bugs and fix them before we rely on them to sustain us all the way to Mars."

**Almost everything needed to do space exploration
can be tested first on the space station.**

Almost everything needed to do space exploration can be tested first on the space station. This is a key part of the international exploration program that will likely be stood up within the next couple of years. Currently, the station's international partners are all talking to each other, trying to determine who ought to be doing what. As Raftery says, "We need the best of what everyone has to offer."

There is no doubt that the International Space Station is very much involved in the future of our nation's space program. But in the final equation, the ultimate success of such an ambitious and exciting program will depend upon collaboration and international partnership.

SPHERES: Formation flying on orbit

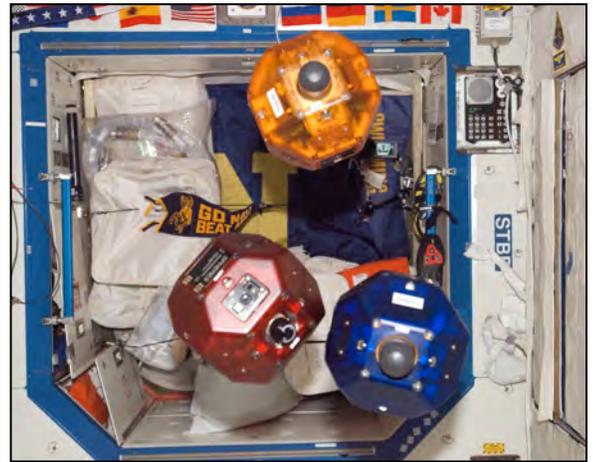
How do we test the ability of free-flying spacecraft to perform autonomous rendezvous and docking maneuvers in zero gravity? The long answer is: We use the internal environment of the space station as a test bed for the testing of multi-body formation flying and multi-spacecraft control algorithms using Synchronized Position Hold, Engage and Reorient Experimental Satellites.

The short answer is SPHERES.

Roughly the size of bowling balls, three 18-sided polyhedron SPHERES have been free flying around inside the space station since late 2003. The satellites communicate with each other and a laptop computer via a low power MHz wireless link. Each satellite is self-contained with an internal propulsion system and power, avionics, software, communications and metrology subsystems that provide real time position and altitude information.

To date, 15 sessions have tested relative altitude control and station-keeping between satellites retargeting and image plane filling maneuvers; collision avoidance; fuel balancing algorithms; and an array of geometry estimators used in various missions. Each session was designed to test progressively more complex two- and three-body maneuvers that involve docking to fixed, moving and tumbling targets, formation flying and searching for "lost" satellites.

As an ongoing technology demonstration, the SPHERES tests may lead to the development of simpler autonomous docking for servicing, resupplying, reconfiguring and upgrading of various space systems. Furthermore, the results will also support the development of autonomous spacecraft that could carry out a broad diversity of tasks in microgravity environments. For example, smaller spacecraft with the right programming and coordination might perform tasks too complicated or too expensive for larger spacecraft to execute.



The Synchronized Position Hold, Engage, Reorient, Experimental Satellites (SPHERES) free-floating in the Destiny laboratory of the International Space Station.

R2: Can a C3PO be far behind?

It's hard not to relate to Robonaut 2, or R2, the most sophisticated humanoid robot ever created, in human terms. Although it can't walk because it doesn't have legs (yet), its torso, arms and head-like structure give it a rather personal presence. Rob Ambrose, R2's NASA dad, explained that getting the robot concept ready for station was a 15-year process and a dream come true — not just for NASA, but for General Motors, a host of universities, Defense Advanced Research Projects Agency, and thousands of space-smitten kids who have eagerly followed its development.

When the Robonaut concept was first advanced, it started somewhat simply — it was first envisioned as a machine designed to work with people in space. But weren't there already robotic elements aboard both station and shuttle? The remote manipulator systems such as the Canadarm on the shuttle and the Canadarm 2 on station are robotic systems, as are the Mars rovers. But Robonaut 2 is the first humanoid system designed to work with astronauts.

The idea, according to Ambrose, was never to replace people, but instead create a robot with the dexterity to handle tools and work side-by-side with spacewalking astronauts as an assistant — a relationship not all that different from that of surgeon and surgical nurse, which was observed in great detail as part of Robonaut 2's development program.

"Surgical nurses are experts at handling tools, anticipating what the surgeon will need next and staying a couple of steps ahead to make sure that the tools are ready at the right time and in the right place," Ambrose explained. "But in our case, our spacewalking astronaut is the expert and the robot would be the assistant, so we wanted to create a helper that could hand tools back and forth, prepare a worksite and even [eventually] put the tools away."

It makes sense. Spacewalks are extremely risky operations for astronauts and are painstaking procedures that require significant rehearsal and preparation time. Ideally, a Robonaut, able to withstand the environmental extremes of space, could take days to set up a worksite. Then when the worksite is ready, the astronaut takes over performing the task that requires judgment and reason, and then the Robonaut closes the task while the astronaut moves on to the next one.

Another key consideration was safety. In human strength terms, Robonaut 2 is actually rather superhuman. So a critical challenge was how to design a robot that was strong enough to do the work, but safe enough and sensitive enough to do the work safely in a side-by-side situation with astronauts. In addition to making R2 a little faster than R1, they made R2's surfaces smoother and softer, padded and loaded with sensors.

"The early Robonauts were covered in padding with all kinds of tactile sensors embedded in the skin coverings to detect the presence and proximity of people," Ambrose said. "We even had vision systems trying to keep an eye on where people were in relation to the robonaut."

Ambrose explained that when NASA started collaborating with General Motors, they discovered that the two entities had a lot in common in regards to what was robotically important. Furthermore, GM's focus on endurance testing and extended lifecycle improved the quality and capability of the robot, which in turn proved critical to getting R2 through the space station's payload safety review panel.

"We invested in a core technology for the robot's drive trains, a series of elastic actuators able to detect forces with an extremely high level of resolution," Ambrose related. "We have three independent layers that each have their own sensors that are always running to monitor forces."

This means that if an astronaut on a spacewalk or a crewmember inside the station floats into R2's workspace and bumps it, R2 pauses and waits until its sensors indicate that the force that impacted it has moved away. Then it goes back to work.

For safety and to handle differing environments, that impact level can be set at any threshold. For work on Earth, it would have to be set at a level to counter the forces of gravity or it would continually be confusing gravity and collisions. But in microgravity, that threshold can be "dialed up" to a very fine level, which makes the robot even safer around people.

Robonaut 2 is destined for the space station on the next mission, STS-133, where it will officially join the station's robotic team. Currently designed to work in a semi-stationary mode, the robot is locked into position with a post or stanchion instead of a pair of legs. It can then let go with its hands and move its upper body freely. R2 will be shipped with a task board populated with many interfaces typically used by crew inside station, as well as interfaces used on spacewalks. The idea is to use the robonaut's first year on station to practice handling the interfaces in microgravity. If problems are encountered in space, then modifications will be made to the software to improve its performance. In effect, they'll practice on the ground, develop what needs to be developed in a less expensive environment and upload the knowledge to the Robonaut on the station.

"Then the robot on station wakes up and thinks it's always known how to do that task or operate that interface," Ambrose said. "So the robots on the ground are our learning platforms and the robots on station are our demonstration platforms."

And while Robonaut 2 is moving through its paces on orbit this year, back on Earth the team will be busy designing a crucial upgrade - a pair of legs destined to be shipped up to orbit next year.



Robonaut 2, a humanoid astronaut helper, will accompany the crew to the International Space Station aboard mission STS-133.

AMS-02: Extra-global collaboration with Nobel potential

What do you get when you combine a bunch of international particle and astro-physicists, a Nobel Laureate project leader, an orbiting laboratory platform and cosmic curiosity?

First, you get one of the most challenging coordination jobs in the history of the space program. Second, you get the attention of astrophysicists, particle physicists and cosmic dreamers all over the world. Third, you get one of the most sophisticated magnetic spectrometers ever conceived or developed – the Alpha Magnetic Spectrometer-02 – and deploy it on an orbiting lab 200 nautical miles up.

Fourth, you pull down enough particle physics data to keep hundreds of scientists busy analyzing for decades. And fifth, you have the potential to answer some of the most profound questions ever pondered when looking up at the night sky: What happened to create our cosmos, how and when? And what exactly is our cosmos made of?

The AMS-02 project, one of the most ambitious international science missions ever envisioned within the broad scope of the space program, would not be possible without the International Space Station as its platform. Scheduled to be launched on Endeavour to station on the STS-134 mission, the AMS-02 will occupy the entire starboard inboard payload attach site and use the unique environment of space to help unravel the mystery of the universe's origin by measuring cosmic rays and searching for anti-matter and dark matter. This space-based, outward-focused experiment promises to define the new frontier in particle physics research as it collects information from cosmic sources (stars and galaxies) millions of light years beyond our Milky Way.

How does it work? The AMS-02 uses a large magnet to produce a strong magnetic field to bend the path of charged cosmic particles as they pass through the instrument's array of detectors. Those include the Transition Radiation Detector, the Time of Flight Detector, the Silicon Tracker Detector, the Ring Image Cerenkov Counter and the Electromagnetic Calorimeter. The AMS-02 also employs two star trackers, a GPS system and uses more than 30,000 data channels as it gathers more than seven gigabytes per second of data. This data will be analyzed, compressed by 650 computers onboard the station and readied for transmission to Earth at approximately six megabits per second. The AMS computers were specifically designed and tested for space applications, so every piece of electronics, including each computer, on the AMS is at least ten to one-hundred times faster than any available aerospace component.

But how did the AMS-02 happen? It's actually a second-generation version of an experiment flown on STS-91 in 1998. AMS-02 is a highly evolved particle physics detector constructed and operated by an international team composed of 60 institutes from 16 countries, organized under U.S. Department of Energy sponsorship and flown by NASA through an intra-agency agreement. The collaborative effort is led by Samuel Ting of MIT, 1976 Nobel Laureate for Physics.

Trent Martin, AMS project manager in the Engineering Office at Johnson Space Center, said that in addition to being responsible for the science, Ting has been the driving force behind convincing collaborators to develop the various pieces and components of the AMS-02.

"That's a key advantage of how we approached the project," Martin said. "We have a \$2 billion space instrument, and the most any one collaborator has contributed is a couple hundred million."

According to Martin, this is both good and bad. It's good because one group doesn't have to pay for everything. It's also bad because such a large number of team members can make collaborating difficult. So that became Martin's job — to make sure that all those different contributors and partners played well in the NASA engineering world.

In addition to seeking answers to the fundamental physics, astrophysics and cosmology questions on the origin and structure of the universe, the AMS-02 will provide accurate measurement of the cosmic ray environment needed to plan the radiation countermeasures required for interplanetary flight.

"It could be a game changer," Martin said.

That's what happens when you combine a bunch of international particle physicists and astrophysicists, a Nobel Laureate project leader, an orbiting laboratory platform and cosmic curiosity.



LIFE AFTER SHUTTLE

What can we learn from those who have already transitioned?

Picture above: Spectators watch from a pier as space shuttle Endeavour launches from NASA's Kennedy Space Center in the early hours of March 11, 2008.

There are so many ways to measure three decades: 133 missions. More than 300 million pounds of cargo. Eight different presidential administrations. However you look at it, 30 years is a long time. Yet through it all, the shuttle program has endured. This is due in no small part to the thousands of individuals who have dedicated themselves to the Space Shuttle Program. And with just two (possibly three) scheduled flights left, that is all coming to an end.

This end brings with it a multitude of questions. What's next for NASA? What will happen to human spaceflight? What will exploration look like in the next 30 years?

But for the men and women who have worked so tirelessly on the longest running human spaceflight program in our nation's history, there is one question that is now more pressing than any other. What does life after shuttle look like?

From the moment the retirement of the shuttle program was announced, there has been a concerted effort to communicate with the workforce – not only from leadership down, but also to send input from the workforce up. Through that process, the program has heard a myriad of concerns, but the one that kept coming up again and again, across all states, centers and contractors was, "What is going to happen to my friends and coworkers?"

It seems working together over the course of the last three decades has built more than just a successful program – it has built a family.

Many people are still working on the answer to that question, but some are already getting a glimpse of what the future holds. In this article, and in subsequent articles featured on the website, we will introduce you to individuals who have made it through the tougher part of transition, and who are finding that there really is life after shuttle.



Casey Roberts

Casey Roberts: The kids are alright

Graduating college is an exciting time. It's made even more exciting when you have a job lined up. And when that job is working within NASA's Space Shuttle Program, it's positively thrilling.

This is exactly the position Casey Roberts found himself in three years ago when he graduated college from Embry Riddle Prescott Campus and was hired as a quality engineer by Alliant Techsystems (ATK) in Promontory, Utah.

"Coming out of college, this was every engineer's dream, to work on the space shuttle," Roberts said.

Roberts split his time between the shuttle program, receiving about 85 percent of his attention, and the Ares Program, receiving the remainder. So, simultaneously, he was working on the marquee spacecraft for the United States space program and developing the next generation of human spaceflight. There really was no better opportunity than to work with and learn from a skilled workforce through the retirement of one program and then

transfer into the new program. It was an exciting time for the newbie; he had landed his dream job and the future was looking bright. And on top of all of that, Roberts wasn't alone. He was hired alongside a wave of peers who were affectionately known as "The Kids" around ATK.

"I remember clearly getting the sense that ATK hired me with intentions of keeping me for the next 20 years," Roberts said.

The vision of a long career with ATK turned fuzzy in February of 2010, when President Obama presented his new vision for human spaceflight. A vision that, by all estimations, was probably not going to include the Constellation Program.

The news reverberated through ATK like so many of the motor tests they had performed.

"Most of 'The Kids' started talking about going somewhere else pretty quickly," Roberts said. "I didn't start making other plans; I didn't think I would be affected."

Roberts wanted to stay on with ATK. His management was keeping a very positive outlook, and there was a lot of hope that things would work out. The workforce at ATK had been working on the Space Shuttle Program from the very beginning and felt like a family – a family he was happy to be a "Kid" in. He didn't want to leave.



ATK Launch Systems in Promontory Point, Utah.

The workforce at ATK had been working on the Space Shuttle Program from the very beginning and felt like a family.

"People really wanted to stay out there," Roberts said. "It's a really close community."

Unfortunately, families don't always get to stay together, and as the months rolled on, the news around ATK wasn't looking great for the young engineer. Given the circumstances, Roberts decided it was time to start looking for new opportunities.

He didn't have to look too far. ATK had plans in place for employees dealing with their uncertain future. The company conducted several job fairs in 2010 and contracted an outplacement service to help employees. Services such as classes on résumé writing, interviewing and networking skills were offered. In addition to classes, one-on-one career counseling was available, as well as assistance for coping with stress. And, if ATK was offering, Roberts was taking advantage.

"I knuckled under and humbled myself and used every resource they had to offer," Roberts said. "ATK put significant effort into helping us find new employment."

Three months after Roberts began looking for new opportunities, his first one came to an end. The day before his last, Roberts remembers his supervisor suggesting "drive your own car in tomorrow instead of taking the van pool." It wasn't an easy time for Roberts, but he decided to make the best of it.

"I saw this as an opportunity to go out and try something new," Roberts said. "It was scary, but now was my chance to make my career what I wanted it to be."



A F-16 Fighting Falcon jet fighter.

Through the resources and job fairs ATK provided, along with his effort and persistence, Roberts took advantage of that chance. He is now working as a structural engineer with the Department of Defense's F-16 Sustainment Program.

"I love it," Roberts said of his new career. "This is the best possible job I could have taken. I received a couple of different offers, but I held out for this one."

When first faced with finding new employment, Roberts was very hesitant. But now that he is on the job, he is finding new levels of satisfaction and fulfillment in his latest career. Now, when asked if he wishes to come back, Roberts has a tough time answering.

"Space is my first love; it's something I'd really like to get back into," Roberts said. "So, I'd have to evaluate that."

Jessica McLaughlin: You can take the girl out of KSC...

Ask anyone who has worked in the shuttle program for a while what their most memorable moment is, and nine out of ten times you're going to hear that it was their first launch. And that's what they call it – *their* first launch. It's not *a* launch or *the* launch. It belongs to those who watched it happen.

For Jessica McLaughlin, it's similar to that, but instead of it being her launch, it's more like her program. She remembers her first launch. It's hers. She remembers her second, too. And her third. Fourth. McLaughlin was a front and center witness for the first ten launches of the Space Shuttle Program. Her program.

McLaughlin grew up in Florida and her grandfather and father both worked for the U.S. government in the KSC area. She grew up right alongside the shuttle program, and it only seemed natural that after college, she would keep right on growing with shuttle. In 2000, McLaughlin began working as an engineer in orbiter processing. She spent seven years at KSC working with low-pressure fluid systems while finishing her doctorate. Seeking new opportunities, McLaughlin came to JSC in 2007 working in the Orbiter Project Office on low-pressure fluid systems and acting as a Mission Evaluation Room manager for two years.

McLaughlin first started hearing about transition back at KSC, though it didn't really catch her or her co-workers' attention as they "kept their heads down and kept working." Reflecting back though, she has mixed emotions about the program retiring.

"It's an American icon, and you are losing one of those assets that the U.S. has, which is a terrible thing," McLaughlin said. "But it also opens new doors to expand in the future ... it's a double-edged sword."

In 2008, when the program reorganized to bring T&R into the mainstream of all program elements, McLaughlin knew that it was really happening and that changes were coming soon. Around the same time, contractors were producing lists of critical needs, which further solidified the fact that the shuttle was going away. McLaughlin needed to start thinking about what was next.

"As a civil servant, you feel protected," McLaughlin said. "There wasn't a lot of anxiety because you know the agency will take care of you. You may not have a job within NASA, but you could go to another government agency. So that wasn't as worrisome; it was more of 'Where do I want to go? What do I want to do?' That's when I started looking."



The launch of space shuttle mission STS-6.

“You may not have a job within NASA, but you could go to another government agency ... so that wasn't as worrisome; it was more of ‘Where do I want to go? What do I want to do?’ That's when I started looking.”

Coming out of an operations world, McLaughlin knew that she wanted to continue to be involved with something that was flying. Enjoying the quick pace of the ops environment made her shudder at the thought of doing anything else.

"I was very influenced by my KSC days," McLaughlin said.

In early 2009, McLaughlin met with her supervisor to map out the next steps of her career. She spent the next several months mulling over the options and seeking advice from coworkers and friends – one of whom worked right across the hall in the Extravehicular Activities (EVA) office. And as luck would have it, there was an opportunity to go on detail in that office.

As McLaughlin found out, sometime the best opportunities are right next door.

"In the morning, instead of turning left, I turn right now," McLaughlin said.

Since starting the detail in October of 2009, McLaughlin has thoroughly enjoyed her work. Not only is she still able to work ops, but she also gets to work with friends, a diverse group of individuals and management that she says is very supportive and "backs you all the way." And, with paperwork wrapped up, McLaughlin's detail will become a permanent position as a spacesuit hardware engineer.

"EVA has a great group," McLaughlin said. "They all love the hardware. They all love the people they work with. How do you not go to work for an organization that absolutely loves what they do? I thoroughly enjoy every day."



Astronauts Low and Wisoff in their EVA spacesuits during STS-57.

Jay Steckman: The transition pro

For some within the shuttle program, transition is a new concept. With three decades of history behind it, many individuals have made a career of the Space Shuttle Program. That's not Jay Steckman's story. The shuttle program is just one stop on a train of transitions.



Jay Steckman

Steckman, now a manufacturing planner with Boeing's 787 Dreamliner Program since February 2010, is a transition veteran. Prior to his current position, he served as Boeing's Ground Support Equipment Manufacturing Liaison at the NASA Shuttle Logistics Depot at Kennedy Space Center, and a technical designer for ground support equipment group on the Space Shuttle Program for six years. Before that, he was with General Dynamics Decision Systems working projects for the U.S. Army in Huntsville, Ala. Prior to that, Allied Signal/Honeywell working turbine engines in Phoenix. And before that he was with Boeing's 777 Airplane program for six years in Seattle.

Transition isn't new to Steckman, but this one was different.

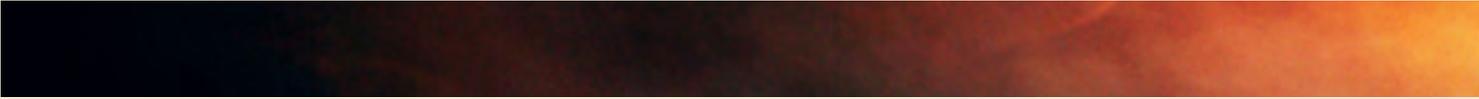
"Transitioning out of the shuttle program was hard for me because it was my career goal," Steckman said. "I had achieved that, and I was just loving every day going to work."

Steckman was loving it so much that the thought of transition wasn't even something he was entertaining. He had worked his whole career to get this far, and didn't want to leave. At the same

time, however, each accomplishment and each launch brought Steckman that much closer to the reality that it was ending.

"It really became apparent when we started saying 'Only nine launches left,'" Steckman said.

It was at that time that Steckman's coworkers really started looking for new work outside of shuttle. Transition still wasn't something that he was really considering, but a new program was opening at the Boeing facility in Charleston, S.C. With several folks transferring there, Steckman's manager brought him an opportunity that he had to consider. Boeing was starting the new Dreamliner Program and needed individuals with experience in a particular computer-aided design, manufacturing and engineering software program – one that Steckman was very familiar with.



"Somehow my skill set was transferred over to management at Boeing Charleston, and the next thing I knew, my name was on the list to go DTA (Domestic Temporary Assignment) up here," Steckman recalled.

"I never really even put in for it, but I was offered it. And I accepted."

Though Steckman really didn't want to transition out of shuttle, he sees the silver lining in the opportunity he's been given.

Through Steckman really didn't want to transition out of shuttle, he sees the silver lining in the opportunity he's been given.

"I didn't want to leave the shuttle program," Steckman said. "I had worked so long to get there that it was hard to even think about leaving it. But then the realization set in, and I was happy I was already a part of the transitioning crowd. It put excitement back into the career."

Steckman is now facing new challenges and processes that he has never experienced before. Prior to this new job, he had always been on the engineering side of the equation. But now he finds himself working manufacturing, which he sees as very exciting.

As exciting as the new opportunity is, transition was still hard. And not just on Steckman.

"Transition is not just about the employee or the job you are taking or leaving," Steckman said. "It's all about your family as well. You're uprooting their jobs and their schools and activities. There's a whole lot involved and a lot of emotions and feelings that come with it."

Much like Steckman, his family is embracing the new opportunities that transition brings. It's still difficult, but they are adjusting. As part of the adjustment, Boeing is helping Steckman's wife with opportunities similar to those that they offer their employees – résumé writing, job placement services and other transition resources.

For Steckman, even after being through so many transitions, it's still tough to get used to. Each transition brings its share of difficulty and stress. There's moving, meeting new people, learning new concepts, handling family needs and adjusting to a new environment — all things that make transition difficult, no matter how many times you do it.

Along with the Boeing leadership and the support of his family, Steckman credits his past experiences with helping him make it through this transition.

"If I just look back at all the little successes I've had along the way, that really helps," Steckman said.

"But I really do miss the shuttle. That was the epitome of it all. It's going to be hard to top that."

Parts of the whole

Over the past three decades the Space Shuttle Program has accomplished more than any other program in human spaceflight history. It has been the workhorse of a nation and deserves to be celebrated. In looking at the program, images of orbiters, solid rocket boosters and external tanks come to mind. Night launches and staggering payloads assembled and launched into orbit and beyond. But for those who worked this program, it is evident that what truly captures the essence of the shuttle program are the people — the thousands of individuals who tell the shuttle story. And part of that story is this final chapter.

This article features three individuals out of the thousands who have been a part of this program. But upon further inspection these three individuals represent so much more. They are civil servants and contractors. They represent launching, landing and payloads. They come from different parts of the country and different generations. They represent families – from those who gathered to watch those first launches to those who are still adjusting to not seeing them anymore.

And, just like these three individuals, there is an entire workforce worth of men and woman who have similar stories. These individuals have made the Space Shuttle Program the success that it is. Their hard work, perseverance, dedication and grit has seen this program through.

Those are attributes that will see the workforce through transition and into the future – into life after shuttle.



Space shuttle Discovery moves along the KSC Crawlerway in preparation for the STS-82 mission.

Editor's Note: It's easy to think that there isn't much going on at NASA outside of shuttle, but as it turns out, there's more. Take a look at "The Meaningful Work We Do."