MARCH 2024

THE INNOVATION CATALYST

NEWSLETTER

Starliner Express

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The Boeing CST-100 Starliner spacecraft was moved into the Hazardous Processing Area at the company's Commercial Crew and Cargo Processing Facility at NASA's Kennedy Space Center in Florida, in advance of power up and fueling operations. Photo credit: NASA

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EVENTS

Byte Sized Talks
Wednesday March 13, 2024
12:00 PM - 1:00 PM
Join us in the building 21 cafeteria for a refreshing twist on the traditional lunch-and-learn format!

This month's Tech Transfer Tip with Senior Technical Writer

Doug Scott

Studying Earth as well as exploring other planets, moons, and asteroids in our solar system presents a wide variety of challenges for Goddard engineers and scientists. Many of those technologies developed and data generated are now commercially used to improve day-to-day life for everyone. SPO is committed to finding ways to move your innovation out of the lab and into the commercial world for much wider use. The next story can be yours!

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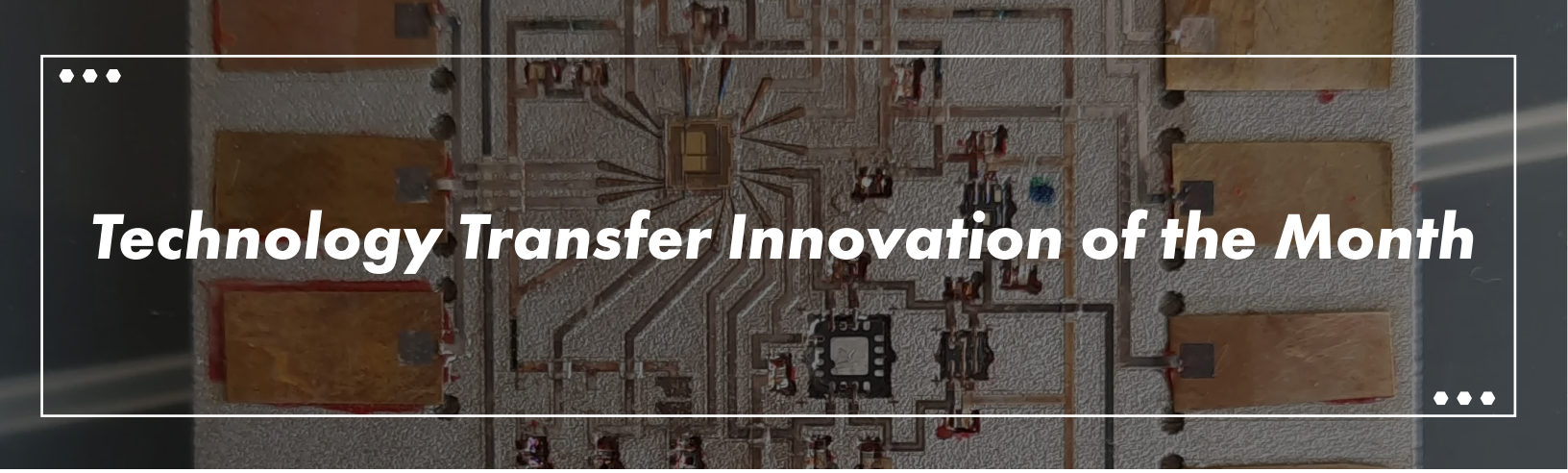


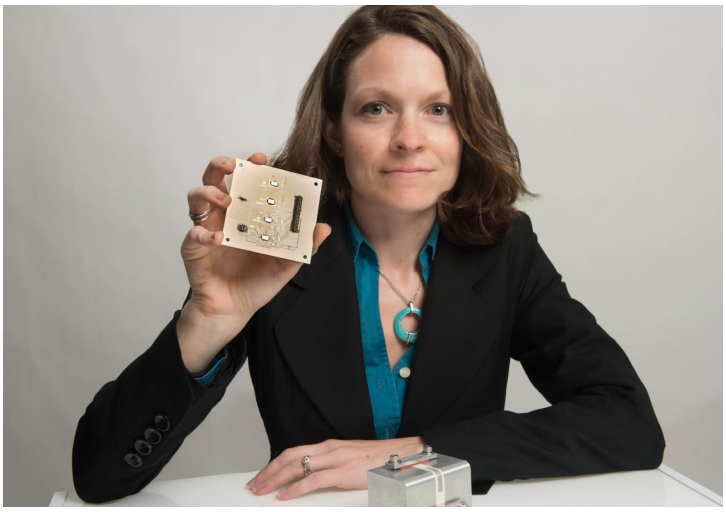
Technology Transfer Innovation of the Month

A printed circuit that flew on the SubTEC 9 technology test flight from NASA's Wallops Flight Facility in April sits on display during the Goddard Field Day event. Photo Credit: NASA/Karl B. Hille

Aerosol Jet Printing Techniques on Next-Gen Microshutter Array Open the Door to New Engineering Possibilities

This is the second of a monthly series highlighting Goddard technologies, which the Strategic Partnership Office (SPO) believes have commercial potential. These are also innovations for which a patent application was recently sent to the United States Patent and Trademark Office for consideration.

In 2019, a team of NASA Goddard engineers and scientists successfully demonstrated a revolutionary array technology for studying hundreds of stars and galaxies at the same time. Called the Next Generation Microshutter Array (NGMSA), the lens or array includes 8,125 tiny shutters, each about the width of a human hair, that open and close as needed to focus on specific celestial objects in space. With observing time at a premium, the ability to gather light from multiple objects at once is paramount.



Goddard electronics packaging engineer Beth Paquette holds a 3-inch-by-3-inch ceramic board with four radiation-hardened digital-to-analog converter chips (in the middle of the board). She created the circuitry using a 3-D printing technique using silver ink. Photo Credit: NASA/W. Hrybyk

NGMSA was successfully used on the James Webb Space Telescope. The challenge for NGMSA as it is considered for future space flight missions is in its assembly design. Traditionally, wire bonding is used to make the interconnections between the integrated circuits and the device itself. However, because the NGMSA array is smaller and denser than those found on most space telescopes, it pushes the limits of existing wire bonding technology. As wire bonding is an inexact process, this technique has suffered from manufacturing and reliability issues when used in harsh environments such as space.

A team of Goddard engineers and scientists have come up with a solution. Beth Paquette, Meng-ping Chang, Matthew Greenhouse, Carl Kotecki, and Kyowon Kim have developed an aerosol jet 3-D printing technique which they called in their patent, an "Additive manufacturing of fine-pitch gold electrodes for next generation micro-shutter array circuitry." Using this unique aerosol jet technique, they can use a 3-D printer to create the kind of tiny micrometer, high-density, high-resolution conductive lines needed for the NGMSA.

"One of the benefits of using aerosol jet printing is that we are able to print small, fine conductive lines from the circuit to the detector pads," explained Paquette, an electronics packaging engineer in the Parts, Packaging and Assembly Technologies Branch (Code 562) and team lead. "So, it is only with the use of aerosol jet printing that we were able to print circuit lines as small as 30 or 20 microns [micrometers], which is what is needed for the NGMSA."

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Goddard astrophysicist Matt Greenhouse and lead engineer Mary Li examine a Next Generation Microshutter array prototype containing 282,624 programmable micro-shutters. Photo Credit: NASA/GSFC

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Developed and patented by a company called Optomec, aerosol jet printing is a technology that effectively produces 3-D printed electronics. The aerosol jet process supports printing on surfaces including plastics, ceramics, and metallic structures. Aerosol jet printing is used for electronic components such as resistors, capacitors, antennas, sensors, and thin film transistors, and eliminates the need for wire bonding.

Optomec worked with the Goddard team to develop this as-yet unnamed aerosol jet printing technique specifically designed for NGMSA. The Albuquerque, New Mexico headquartered company has shown interest in commercializing this technique once it receives a patent and is available for licensure.

Chang, an electronics engineer with the Detector Systems Branch (Code 553), believes that there are potential commercial applications for this aerosol jet technique that go beyond its use in NGMSA. With SmallSats and CubeSats attempting to pack sensors, guidance, control, and other operating electronics into every available inch of space aboard a spacecraft, the ability to print electronic technology using the aerosol jet process on the walls and structures of a spacecraft could help future missions.

"Anything that needs to be miniaturized can benefit from this technology," said Chang. "It could be sensors for an automobile or wearable applications, actuators, or microchips. The key here is aerosol jet 3-D printing offers an opportunity to fabricate the circuit interconnection after the product or device has been made. For example, this can be used to print the electronics on a SmallSat or other space applications. When people see this, they will see the benefit of this technique. We are offering a bridge to the latest technology."

One advantage of aerosol jet printing is electrical components can also be printed onto 3-D surfaces, eliminating the need for a separate substrate thereby reducing the size, thickness, and weight of the end product. For example, aerosol

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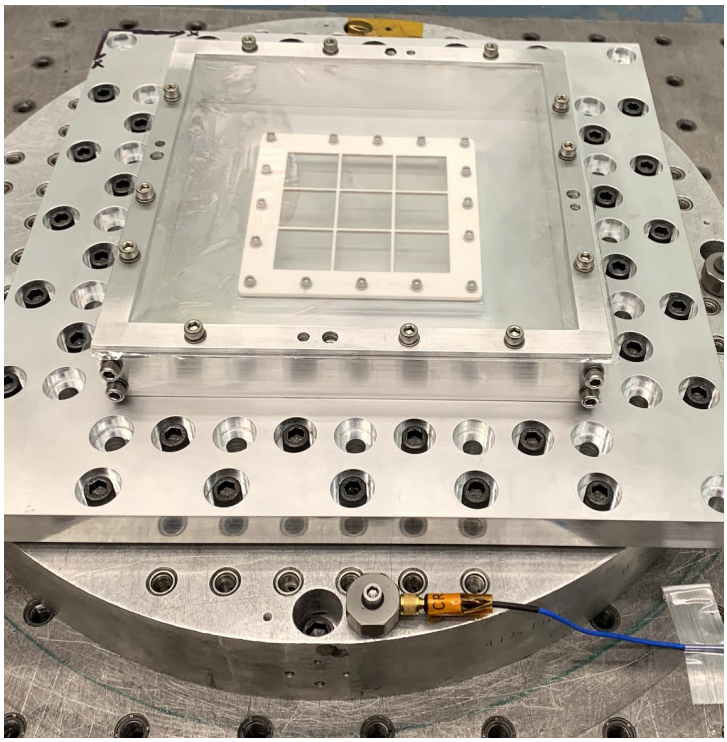
jet can be used to print antennas or sensors that conform to the shape of an underlying substrate, such as a spacecraft.

In fact, this kind of application has already been tested. Last year Paquette and Goddard Electronics Engineer Margaret Samuels sought to prove the space-readiness of printed electronics technology. They successfully tested hybrid printed circuits in space aboard NASA Goddard's SubTEC-9 sounding rocket mission.

"The uniqueness of this technology is being able to print a sensor actually where you need it," said Samuels. "The big benefit is that it's a space saver. We can print on three-dimensional surfaces with traces of about 30 microns – half the width of a human hair – or smaller between components. It could provide other benefits for antennas and radio frequency applications."

According to Paquette, temperature sensors could be printed all over a spacecraft's surface interiors on future missions. For example, she said, that type of mission could analyze the heating of a spacecraft as it travels closer to the Sun.

"I have been working on additive manufacturing of electronics for almost 10 years now, so it is nice to finally see some application come together and benefiting some other technology," said Paquette. "I am excited to see where it goes next."



An image of a 282.6K-pixel NGMSA mechanical structure hybrid mounted on a vibration table for random vibe and acoustic vibe tests. Photo Credit: NASA/GSFC

Advantage of Aerosol Jet Printing

The idea of using printing technology to manufacture electronics dates back to the early 20th century, but its use didn't become prevalent until the 1950s. Still, it was not until the late 1990s that the Defense Advanced Research Program Agency (DARPA) initiated a project to develop a new tool specifically designed for the printing of electronics. The project, named Mesoscale Integrated Conformal Electronics (MICE), developed something called aerosol jet printing. That is how aerosol jet first became an additive manufacturing technology for 3-D printed electronics.

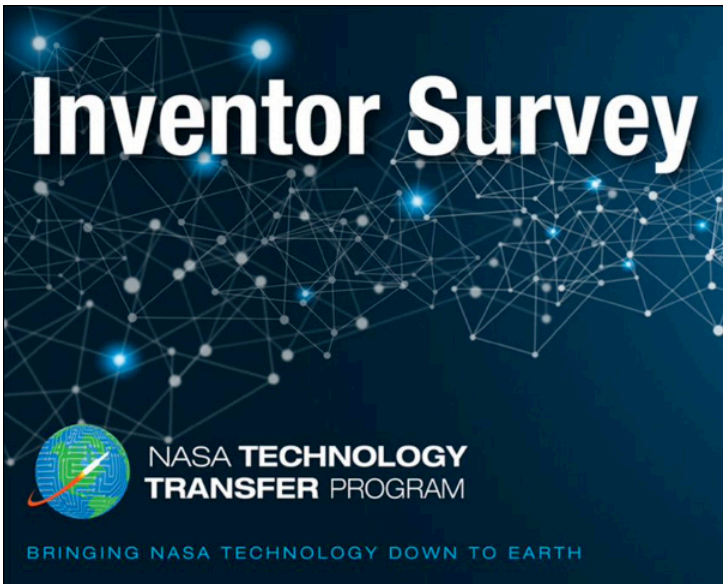
For many 2-D applications, conventional manufacturing methods like wire bonding work. But with smaller, thinner, smart connected devices used in consumer electronics, aerospace, healthcare, and internet of things applications, new 3-D manufacturing methods are required. Below summarizes the advantages of aerosol jet technology for these applications.

- Digital printing – no masks or stencils
- No plating or etching required
- Feature sizes from 10 microns to millimeters
- Print thickness from 100 nanometers to 10s of microns
- Conformal printing on non-planar and 3-D surfaces
- Print interconnects and active/passive components
- Print using commercially available materials
- Print biomaterials
- Print on plastic, ceramic, and metallic substrates
- Scalable to support high-volume production requirements

NASA Inventor Survey Concludes Innovators are Satisfied with the NTR Process

Survey Also Highlights Importance of Communication Between Tech Transfer Managers, Inventors

For many years, the Strategic Partnership Office (SPO) at Goddard has been reminding engineers and scientists working on developing a new technology, innovation, or idea, to fill out an NTR. So, how do NASA engineers and scientists really feel about the NTR process, technology transfer, and ultimately applying for a patent with the United States Patent and Trademark Office? Overall, newly released survey results suggest that most inventors understand the NTR submission process well and have had positive experiences with it.



To find out if NASA engineers and scientists understand the tech transfer process and to better gauge their overall NTR reporting experience, NASA's Technology Transfer Office hired a contractor to conduct an Inventor Survey. Between August 24, 2023, and September 22, 2023, Alexandria, Virginia-based BryceTech sent the survey to 2,723 civil servants who had submitted or co-submitted at least one NTR since 2018. That includes engineers and scientists from all the NASA centers, including Goddard.

Respondents were given 15 questions, some of which were multiple choice while others were open-ended, allowing inventors to write their own individual responses. The questions focused on everything from gauging an inventor's level of interest in filing an NTR to their level of support for the tech transfer program and activities. About half of the responders said they had filed more than three NTRs. Just over half said they had been at NASA more than 20 years and also pursued a patent for their innovation.

"What this told us is that most of the representative population that took the survey were not first-time [NTR] users and they had a lot of submissions," said Jason Hay, director of Technology at BryceTech and team lead of the survey. "We targeted the 15 questions to inventors to understand the depth of their understanding of the NTR process and what their role is within the process. We were able to glean some very interesting data from the information that they provided."

In February, BryceTech revealed the results of the 2023 NASA Inventor Survey to SPO and the rest of the NASA tech transfer community. Among the key takeaways: 1) the majority of respondents were satisfied with the NTR process, 2) they felt motivated to promote NASA technologies, 3) they were aware of the NTR requirements, and 4) they were interested in supporting a wide range of NASA tech transfer activities. However, respondents also felt unclear about NASA's evaluation process for filing a patent based on their submitted NTRs and did not feel they received an option to patent their own technology. They also were "not interested" in participating in tech transfer webinars.

One Goddard inventor from the survey responded, "It was simple to submit an NTR, but the overall process wasn't very

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clear." An innovator from the Langley Research Center wrote, "The forms are trying to get different answers to each field [in the NTR] but it feels like I had to repeat the [same] information many times. A little more description on the fields would be helpful to file the NTR."

Still, respondents were highly motivated to support tech transfer. An Ames Research Center inventor who took the survey wrote, "What really motivates me and gets me to advocate that others do NTRs, is that, after working on something for a year or more, you really want it to live on after NASA moves along and assigns you to work on something else." Another inventor at the Johnson Space Center wrote that tech transfer was important because, "Technology developed at NASA should be available in commercial industry."

BryceTech estimated that between 76 percent and 68 percent of responders said they were happy to support tech transfer activities. Those activities include providing technical expertise to entrepreneurs and NASA-sponsored commercialization accelerators, attending conferences, answering questions from companies, talking to students, and supporting tests and evaluations. Overall, BryceTech concluded that 60 percent of respondents felt they were either very satisfied or somewhat satisfied with the NTR submission process.

"One of the things that we were trying to learn from this survey is how many of the respondents were actually pursuing a patent at the end of the NTR process," said Hay. "The majority of respondents did. This is an indication that people struck through the entire process from initial disclosure to patent. This helped to provide us with some insight into how they found the NTR process to be of their satisfaction."

Hay went on to comment that it would be "fantastic to say that this was a representation of innovation at NASA in that over half the innovations at NASA were patentable." But that was not what he felt this metric was meant to illustrate. Rather he said as NASA moves to next steps, "This begs the question, what should the NTR patent rate be? How many disclosures of patents would be considered a success rate from a technology transfer perspective? These are questions the NASA Technology Transfer Office will now have to grapple with."

The findings also highlight the importance of clear communication between tech transfer managers and the inventors and ensuring that inventors understand what is and what is not a patentable technology from NASA's perspective. If you have questions about these or other issues related to tech transfer, please contact SPO or your tech transfer manager.

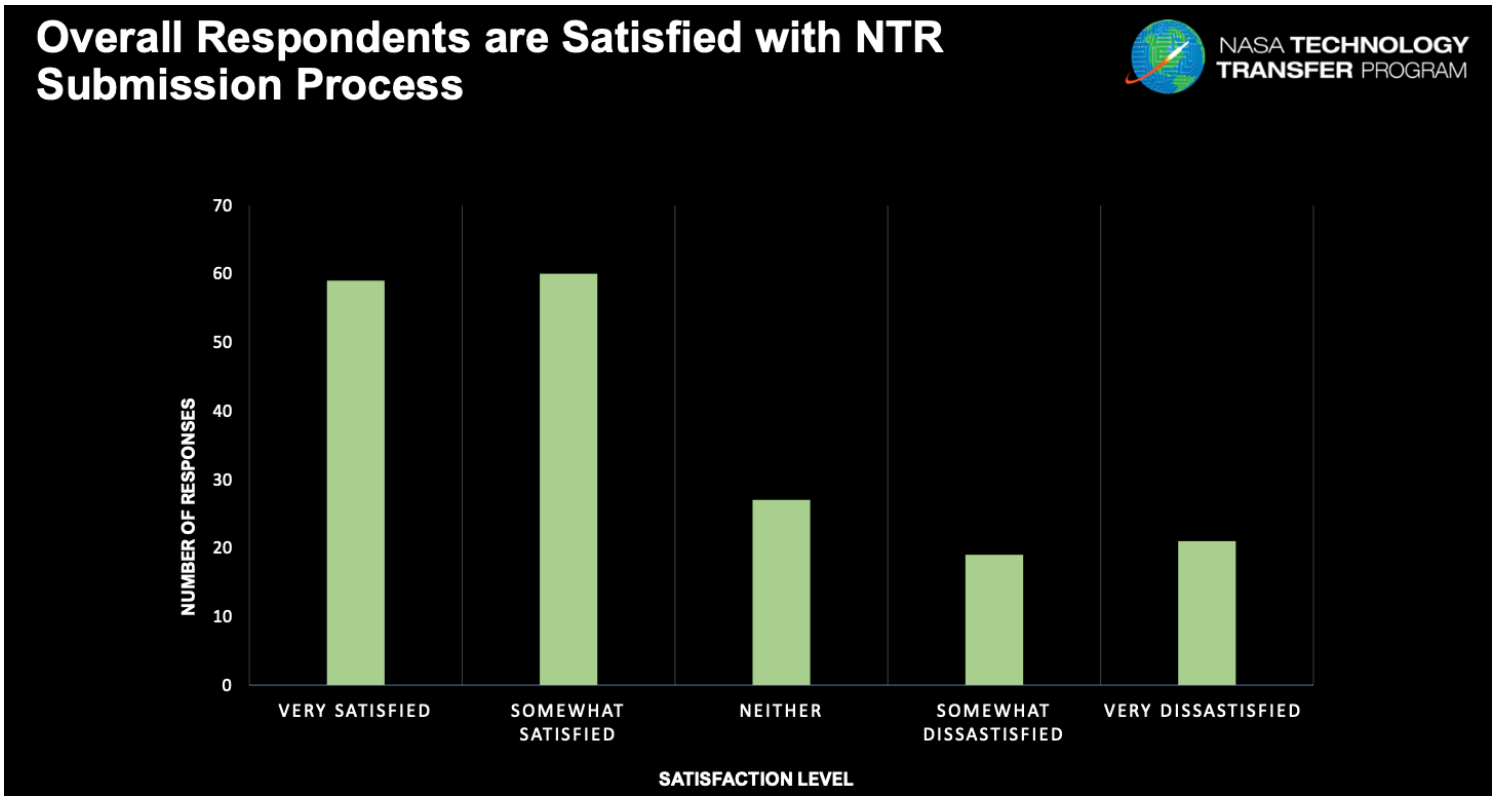

Image Credit: BryceTech

A NASA C-130 cargo aircraft releases a dart-shaped test vehicle above the U.S. Army's Yuma Proving Ground on Jan. 9 to begin the testing sequence for a Boeing Starliner parachute system. Photo Credit: U.S. Army Yuma Proving Ground

NASA Goddard Partnerships in Action

Successful Parachute System Test Paves the Way for Launch of Boeing's Starliner Spacecraft to the International Space Station

A parachute system for Boeing's Starliner spacecraft for NASA's Commercial Crew Program (CCP) was successfully tested over the Yuma Proving Grounds in the Arizona desert on January 9, 2024. NASA concludes the preliminary data analysis from the parachute test suggests that the primary test objectives are met.

Goddard's Wallops Aircraft Office and Boeing are now working together to prepare Starliner's first crewed fight to and from the International Space Station. The successful parachute system test was a key step in the partnership developed between NASA Goddard and Boeing.

Boeing's Crew Space Transportation (CST)-100 Starliner spacecraft is being developed in collaboration with NASA under the CCP). The purpose of CCP is to develop commercially operated crew transportation to and from the International Space Station.

NASA Goddard and Boeing are now proceeding with preparations for the Starliner spacecraft crew flight test to carry astronauts to the International Space Station. The mission is currently slated to launch no earlier than mid-April and lasting approximately 10 days. This critical commercial crew parachute airdrop test in January, was paramount to ensuring the safety of astronauts returning to Earth.

"Our work here is a shining example of our Goddard 2040 Vector 5 goal of growing partnerships and collaborations; in this case both within NASA and industry," said Center Director Dr. Makenzie Lystrup. "The importance of partnerships to meet the needs of the future cannot be overstated, and it's why a key part of the NASA and Goddard 2040 strategies include expanding our collaborations."

Goddard 2040 is a center-wide plan to provide a "snapshot" of where the center is today and to develop a roadmap for the journey ahead. Goddard leadership developed seven Vectors or what Lystrup calls "the guiding stars" of what Goddard will be shepherded by as the center moves forward over the next 16 years. These seven Vectors are designed to help people make decisions on the kinds of investments that Goddard needs to make every day – including for example, who the center forms partnerships with.

Vector 5 in this plan is Expanding Our Collaborations and Partnerships. This Vector focuses on creating an easier pathway for Goddard to share its inventions and science knowledge through technology transfer with the private sector, the aerospace industry, academia and non-profits. A complete detailed explanation of all seven Vectors and a complete

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The Starliner team works to finalize the mate of the crew module and new service module for NASA's Boeing Crew Flight Test that will take NASA astronauts Barry "Butch" Wilmore and Sunita "Suni" Williams to and from the International Space Station. Photo credit: Boeing/John Grant

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description of Goddard 2040 can be found by visiting Goddard's internal Sharepoint site at https://nasa.sharepoint.com/sites/gsfc and by clicking the quick link to the Goddard 2040 Strategic Vision Booklet.

"Partnerships brings us all kinds of advantages," emphasized NASA Administrator Bill Nelson. "The additional creativity and ideas that come out of partnerships and the additional resources that come out of partnerships. So, partnerships for the future are essential for us."

Starliner is an innovative, weldless space capsule, which was initially designed to accommodate seven astronauts, or a mix of crew and cargo, for missions to LEO (low-Earth orbit). For NASA's service missions to the International Space Station, it will carry up to four NASA-sponsored crew members and time-critical scientific research.

Starliner is reusable for up to 10 missions with a six-month turnaround time. It also features wireless internet and tablet technology for crew interfaces. "Every working day, I bring a mindset of knowing that what we do will lead to a successful launch and return to Earth," said Mike Dahm, lead test conductor and lead test engineer at Boeing for its Starliner spacecraft.

As with other space capsules, Starliner relies on parachutes to land astronauts safely when it returns to Earth. In January, a C-130 cargo aircraft from Goddard's Wallops Flight Facility, carried the test parachutes high above the U.S. Army's Yuma Proving Ground before releasing them. Mimicking the soft-landing velocity experienced of the spacecraft's return to Earth, Starliner's flight-like main pilot parachutes fully inflated.

The Starliner parachute system drop test was specifically performed to confirm the functioning of a redesigned and strengthened soft link joint that is part of the network of lines connecting the parachutes to the spacecraft. The test also validated a change to strengthen one textile joint in the parachute, increasing overall parachute robustness.

Starliner's crew flight test is scheduled to launch NASA astronauts Butch Wilmore and Suni Williams to the orbiting International Space Station for a stay of one- to two weeks before returning them to a landing in the southwest United States. The mission will mirror the tasks of regular crew rotation flights for Boeing's Starliner under contracts with CCP.

A pair of parachutes lower the dart-shaped test vehicle to the ground to conclude the drop test for a modified parachute for the Starliner spacecraft. Photo Credit: U.S. Army Yuma Proving Ground