National Aeronautics and Space Administration

# A Year in Review 2023 from NASA's Agency Chief Technologist

## NASA's Office of Technology, Policy, and Strategy

December 2023

Office of Technology, Policy, and Strategy

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**Front and back image:** In this Hubble Space Telescope portrait, the giant red nebula (NGC 2014) and its smaller blue neighbor (NGC 2020) are part of a vast star-forming region in the Large Magellanic Cloud, a satellite galaxy of the Milky Way, located 163,000 light-years away. The image is nicknamed the "Cosmic Reef," because NGC 2014 resembles part of a coral reef floating in a vast sea of stars.

**Figure 1:** Successful hot-fire test of a liquid oxygen/methane (LOX/LCH4) injector and nozzle using new NASA alloy GRX-810. The GRX-810 alloy has incredible performance benefits in extreme environments and was featured in 2023 in Nature Magazine. NASA's center chief technologists champion such efforts in the agency and assist execution of funding programs to develop breakthrough advances.

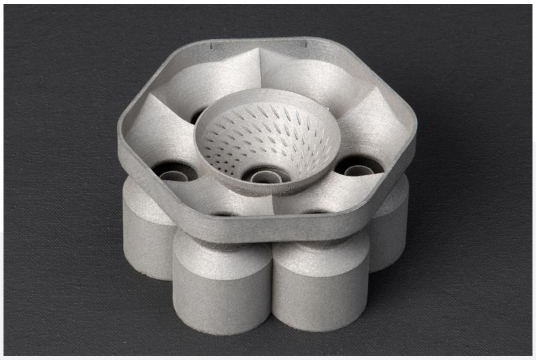

**Figure 2:** This turbine engine combustor (fuel-air mixer) was 3D-printed at NASA Glenn Research Center (GRC) and is one example of a challenging component that can benefit from applying a new alloy called GRX-810. The NASA alloy GRX-810, an oxide dispersion strengthened (ODS) alloy, can endure temperatures over 2,000 degrees Fahrenheit, is more malleable, and can survive more than 1,000 times longer than existing state-of-the-art alloys. This new alloy can be used to build aerospace parts for high temperature applications, like those inside aircraft and rocket engines, because ODS alloys can withstand harsher conditions before reaching their breaking point.

# Technology at NASA

## Annual Letter from Agency Chief Technologist A.C. Charania

> *"Smartly understanding technology now, jump-starting new, and championing the infusion into next missions with all deliberate speed using light and leverage."*

This letter is a review of the last year, which was my first year as the agency chief technologist, or ACT. This role, which has been around for more than decade, has changed over the years, and now resides with the Office of Technology, Policy, and Strategy (OTPS) within the Administrator's office at NASA Headquarters. My approach in this year in review is to look at technology-related studies within OTPS and to showcase the agencywide team of center chief technologists that support me. I took this position as ACT to help the NASA mission, to prepare the agency for the future, and to continue the momentum of partnerships with external organizations. This last point directly leverages my more than two decades of experience of collaborating with NASA from my previous vantage point of commercial industry.

I have used the last year to listen to our internal NASA teams, explore the various centers and their capabilities, and understand where I could be most helpful as the ACT.

The first step in any strategy is problem identification and that has been the lens I have used for the last year. Over the last few months, I have taken these inputs and come out with a vision statement of this ACT that I am using to keep myself focused on those efforts where I would like to make progress over the next few years: "Smartly understanding technology now, jump-starting new, and championing the infusion into next missions with all deliberate speed using light and leverage."


**Figure 3:** Agency Chief Technologist (ACT) A.C. Charania presents to the Center Technology Council (CTC) during a quarterly face-to-face meeting at NASA Headquarters in August 2023.


**Figure 4:** The Center Technology Council (CTC) and NASA's Office of Technology Policy and Strategy (OTPS) conducted their quarterly face-to-face meeting in February of 2023 at NASA Headquarters. Back row (L-R): John Dankanich, Peter Hughes, Kurt Sacksteder, Nicholas Skytland, Harry Partridge, and Thomas Cwik. Front row (L-R): David Voracek, Bhanu Sood, Kelvin Ruiz, Julie Williams-Byrd, A.C. Charania, Kathleen Loftin, Phillip Williams, John Carr, and Charles Norton.

## "Smartly understanding now" –

My role as "principal advisor to NASA senior leadership … on matters concerning agencywide technology policy and programs," along with the charter to "conduct annual review and assessment of technology investments across the agency" means that I plan to work in close coordination across NASA to collect, analyze, and report on the agency's technology investment portfolio. This includes an annual process I call the Technology Analytics Research & Development Inventory Study (TARDIS).

## "Jump-starting new" –

I want to leverage our analytical capabilities in OTPS and as the ACT in helping to understand and develop a more optimized approach to how NASA looks at research and development funding. This includes specifically helping to optimize our use of Internal Research and Development (IRAD) funding. This area includes helping the agency examine and leverage technology areas as exemplified by artificial intelligence (AI) and quantum.

**Figure 5:** The NASA Center Technology Council (CTC) and the Office of Technology Policy and Strategy (OTPS) at a quarterly face-to-face meeting at NASA Glenn Research Center (GRC) in June 2023. Back row (L-R): Ave Kludze, Peter Hughes, Jill Bauman, Max Briggs, Thomas Cwik, Nicholas Skytland, Kurt Sacksteder. Front row (L-R): Kelvin Ruiz, Timothy Griffin, Kendrick Glenn, Charles Norton, Julie Williams-Byrd, John Carr, David Voracek, Ronnie Clayton, A.C. Charania, Alyse Beauchemin.

## "Championing the infusion of" –

I believe there is more to be done in the areas of overcoming the technology infusion "Valley of Death," as I call it. An analogy one can make to the Defense Advanced Research Projects Agency (DARPA) problem of transitioning technologies into a military service program of record, where for NASA, it is transitioning into a mission. I think there are multiple innovative approaches we need to examine to help overcome this problem.

I have various tools at my disposal to affect this positive change, mainly the analytical resources within OTPS, the support from the center chief technologists, my engagements with other government agencies, the entire NASA 2040 initiative, and my engagements with our external commercial and international community.

I felt that we made progress on various studies in emerging technology areas such as quantum, supported more strategic thinking in the agency's approach to artificial intelligence, supported the efforts to help optimize the agency's operational model through working on the NASA 2040 Technology workstream as its owner, helped to understand the challenges with agency Internal Research and Development (IRAD), and engagement with other government agencies, internationals, our domestic U.S. industrial base, and academia.

**Figure 6:** The NASA Center Technology Council (CTC) and OTPS team members during a quarterly face-to-face meeting in Las Vegas, Nevada (after the AIAA ASCEND 2023 conference) in October 2023.

**Figure 7:** As part of the quarterly face-to-face meeting in October 2023, the NASA Center Technology Council (CTC) conducted an on-site technical tour of the Las Vegas Sphere to understand the innovative processes and technologies that led to its creation.

Next year I look forward to focused studies and activities to rapidly effect positive change for not only NASA but for the entire Nation.

**A.C. Charania**
Agency Chief Technologist (ACT)
Office of Technology, Policy, and Strategy (OTPS)

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# Chapter 1:
# Leadership and Organizational Overview

## Office of Technology, Policy, and Strategy and the Agency Chief Technologist

The Office of Technology, Policy, and Strategy (OTPS) provides NASA's senior leadership with independent, data-driven analyses to inform the most consequential decisions about NASA's future.

Housed within the Office of the Administrator, OTPS brings together diverse, multidisciplinary experts to provide NASA leadership with analytic, strategic, and decisional insights in the form of quick-turn analyses, memos, and reports. OTPS also supports numerous activities that include hosting informal discussion sessions, participating in chartered interagency working groups, and funding external research opportunities.

For a detailed look at OTPS's accomplishments this year, please read the office's annual report, ***NASA's Office of Technology, Policy, and Strategy A Year in Review 2023.***

Technology plays a critical role in NASA's mission to innovate for the benefit of humanity by creating solutions for space exploration that also generate tangible benefits for life on Earth. Residing within OTPS, the agency chief technologist (ACT) serves as the principal advisor to NASA senior leadership on matters concerning agencywide technology policy and programs.

**Figure 8:** The Center Technology Council attends a face-to-face meeting at the Glenn Research Center in June of 2023.

The ACT collaborates across the agency and with other federal agencies, and engages with external partners to give NASA leadership a holistic view of NASA's existing technological capabilities and opportunities. The ACT provides leadership focus on emerging and disruptive technologies that may fundamentally change NASA's technology choices for its missions.

The ACT and OTPS conduct relevant technology studies and analytics that a mission directorate or NASA center may not be able to conduct on its own. For example, the Technology Analytics Research & Development Inventory Study (TARDIS) is one such study that will optimize understanding of NASA's technology inventory and help infuse technologies into NASA missions. The ACT is also NASA's representative to the Space Science and Technology Partnerships forum with participation from other OTPS team members and counterparts from the National Reconnaissance Office and the United States Space Force.

The intelligence and insight of NASA employees is the agency's greatest asset. The solutions to some of the largest technological and strategic challenges that NASA faces lie with the very people most familiar with our systems and processes. To best evaluate solutions to particular problems, OTPS offers a one-year

**Solver-in-Residence (SiR)** detail opportunity to evaluate a range of solutions to a particular challenge aligned with one or more of OTPS's focus areas. In FY 2024, the SiR will have a technology focus and will investigate how to align the development and use of autonomy technologies, including artificial intelligence, across the whole of NASA.

## About the Center Technology Council

The NASA center chief technologists (CCTs) and their deputies (DCCTs) support the ACT's various technical endeavors and act as subject matter experts for the agency. CCTs and DCCTs comprise the Center Technology Council (CTC), which reports to the Office of Technology, Policy, and Strategy (OTPS), under the agency chief technologist (ACT).

**Figure 9:** The NASA Center Technology Council tours the Simulated Lunar Operations Laboratory (SLOPE) at Glenn Research Center in June 2023.

The CTC responsibilities include:

1. Assessing the agency technology road mapping and prioritization activities from a bottoms-up, institutional perspective, and providing these assessments to the ACT and NASA Leadership.
2. Providing the ACT and NASA Leadership with recommended changes in technology program scope, prioritization, and roadmapping from the centers' perspectives.
3. Providing the ACT and NASA Leadership with "beyond-program" technology inputs for potential future development.
4. Developing center reports on the performance of the innovation and technology development activities at each center.
5. Identifying inter-center technology leveraging opportunities.
6. Developing technology intelligence reports (that is, have the function to look outside the walls of NASA for technology opportunities).

# The Center Technology Council (CTC)

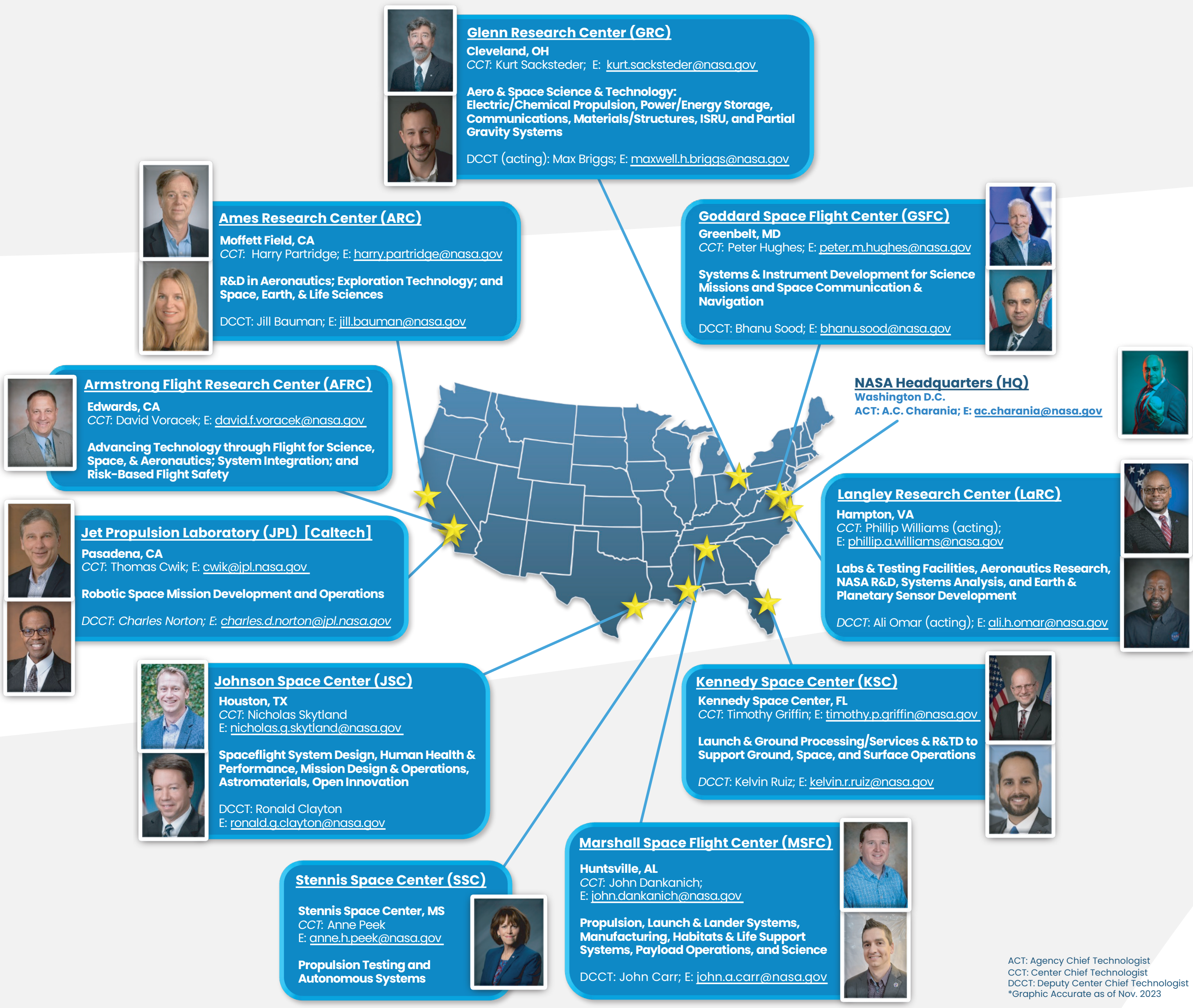



**Figure 10:** NASA centers and the NASA center chief technologists.

# Chapter 2:
# Smartly Understanding Now – NASA's Technology Inventory

One of the duties of any technologist at any organization is to understand the current state of investment - to understand the now. When the agency chief technologist came to NASA, he identified that he could provide executive leadership with a holistic look at NASA technology investments across directorates and centers. This is not to specifically prioritize funding but to help the agency understand its investments to help better guide decision makers, understand trends in investments, make NASA data collection better, and help advocate better for technology investment. The ACT views this as an important part of their legacy to the agency as a whole and to the next ACT.

Fortunately, for more than a decade NASA's TechPort system has been continually refined and improved as a tool for showcasing and cataloging technology investment information from across NASA. It currently has 1,200 active projects. The ACT and OTPS are leveraging this database as the starting point to understand the current NASA inventory of technologies.

The Space Technology Mission Directorate (STMD) TechPort systems defines a technology as "a solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem to enable a specific capability." This inventory is intended to capture research and development (R&D) technology projects that fall under the categories of applied research and experimental development.

Using technology investment data from TechPort and the directorates, ACT and OTPS team members are moving forward with an annual process called the **Technology Analytics Research & Development Inventory Study (TARDIS)**.

The TARDIS process will work in concert with the existing TechPort data collection processes to encourage better reporting across all mission directorates and centers. The agency has over the years developed the TechPort system. The ACT plans to utilize this system and encourage the agency to make it a more complete reference.

A nominal annual schedule has been outlined for the TARDIS process. The schedule starts every October when the ACT meets with the TechPort Configuration Control Board to communicate the plans for data collection, analyses, and reporting. Each NASA mission directorate and center will be encouraged to ensure their end of fiscal year data is up to date and captured in the system by January. The products of this analysis will be an annual assessment of the agency's technology portfolio to be presented to NASA leadership and other stakeholder audiences. Over time, this process will help scope out more built-in analyses in the TechPort system that can provide more rapid and informative assessments of the agency's technology portfolio.

The data will be used to ask questions about NASA's technology inventory. Examples of such questions include:

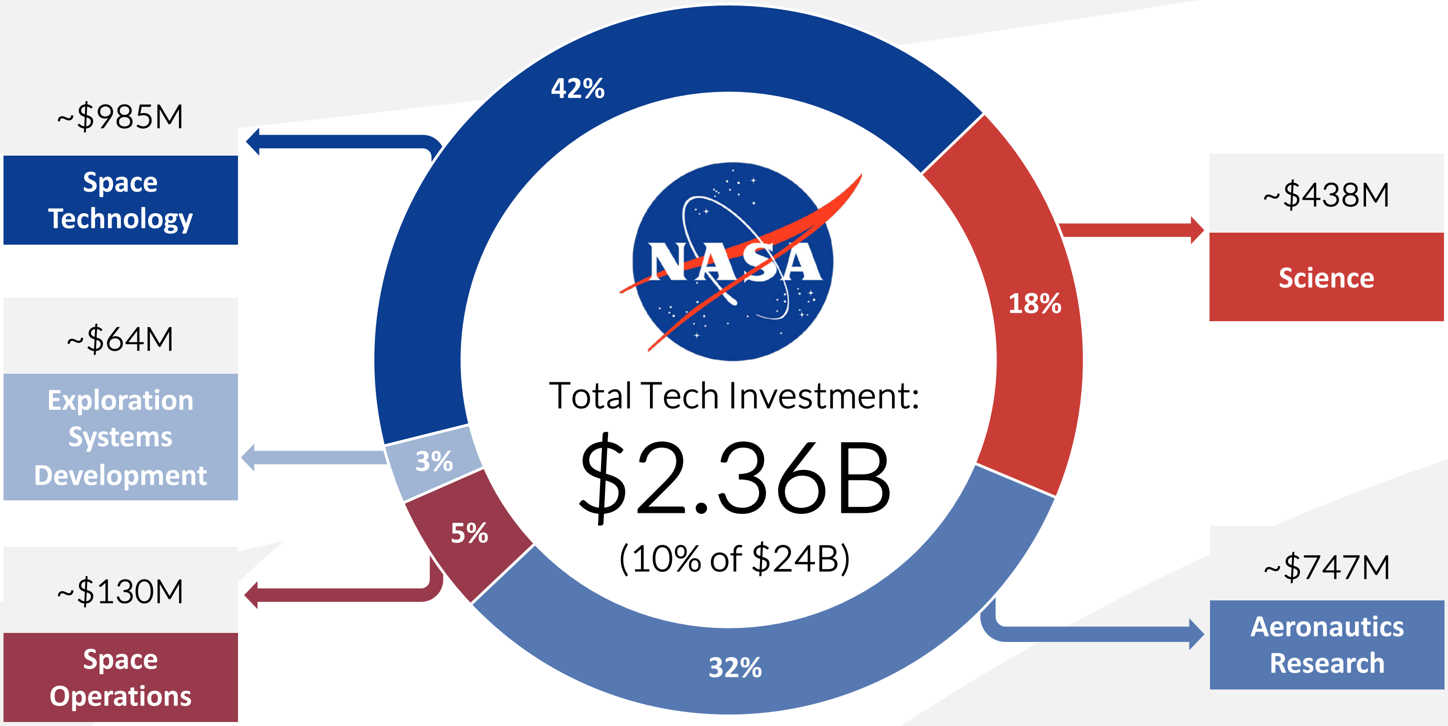
- How is NASA investing in early-stage technologies?
- What technology investments is NASA making to support current and future mission needs?
- How are NASA's technology investments aligned with the goals of NASA's future vision?

It is anticipated that the technology inventory analyses will be reported to internal and external stakeholders every March or April for the prior fiscal year.

Figure 11 shows NASA's technology investments by mission directorate and lists NASA's technology development programs. In FY 2022, NASA invested about $2.36 billion in technology development, about 10 percent of NASA's budget.

The ACT worked hand in hand with NASA's Mission Directorates to initiate an update to NASA's technology investment inventory. It will support NASA leadership ability to make data-driven decisions and provide transparency to industry, government, academia, and the American public on NASA's technology investments. These data are significant because they mark the beginning of the TARDIS process at NASA.

## NASA Technology Inventory Snapshot by Mission Directorate in Fiscal Year 2022




- *Funding amounts and technology programs are self-reported by each Mission Directorate*
- *Exploration Systems Development Mission Directorate R&D does not include all technology development in the Directorate*

**Figure 11:** Pie chart depicting the breakdown of NASA Mission Directorate technology investment spending in Fiscal Year 2022.

Figure 11 describes the breakdown of NASA's FY 2022 technology investments per mission directorate. The Space Technology Mission Directorate (STMD) had the largest piece of this pie with 42% of the $2.36 billion total allocated to NASA technology investments.

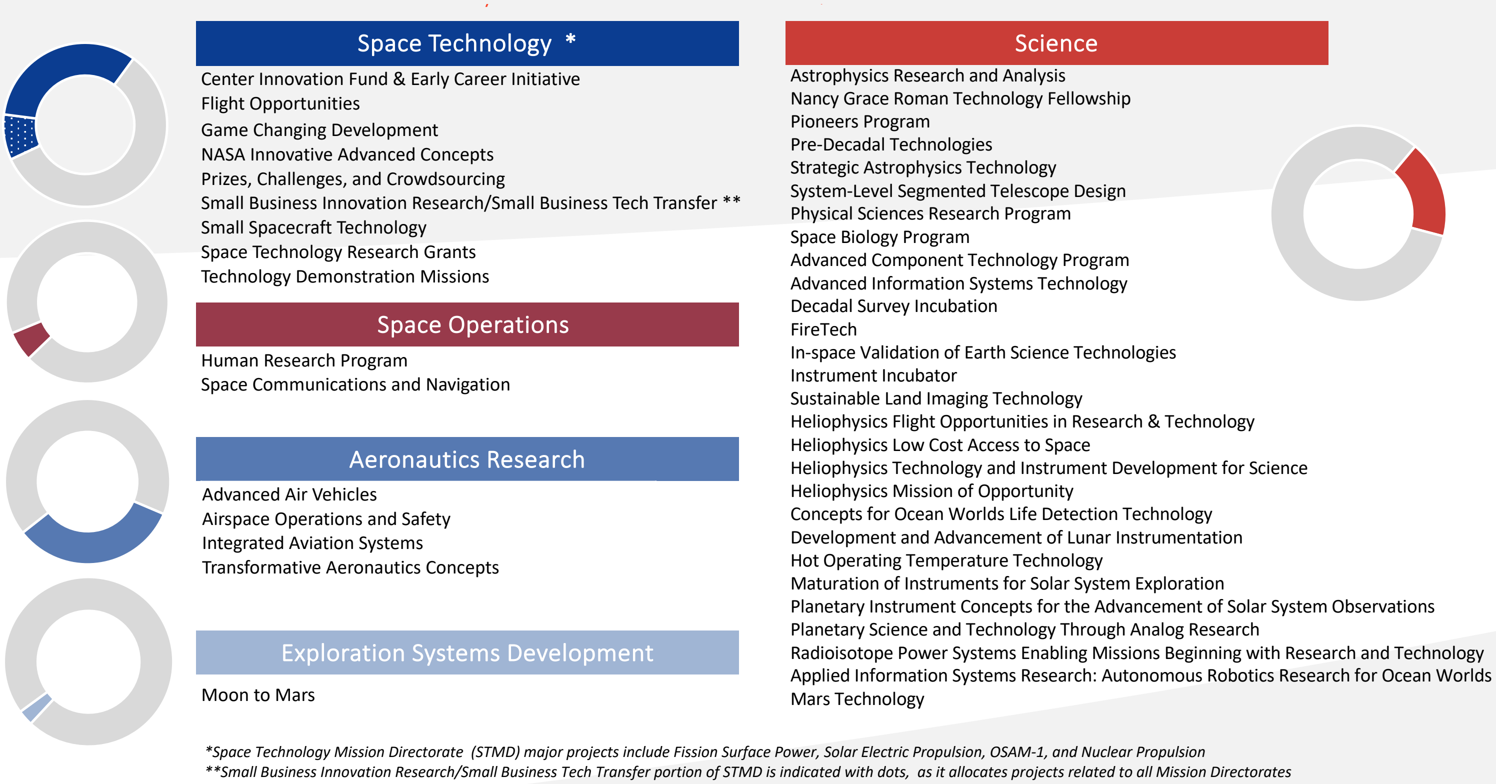



**Figure 12:** Chart depicting the areas of technology investment per NASA Mission Directorate in Fiscal Year 2022.

Figure 12 breaks down the technology areas in each Mission Directorate that received investment funding. While STMD received the largest portion of funding, the Science Mission Directorate (SMD) funded the most technologies.

# Chapter 3: Select OTPS Technology Studies

Throughout 2023, OTPS team members have worked on or are completing studies relating to work under the technology portfolio in the areas of quantum sensing, active debris removal, technology scouting, and wildfire technology inventory. The following section briefly provides summaries of each of these studies.

## Quantum Sensing

### *Interagency Quantum Sensing Study*

Quantum sensors rely on quantum mechanical properties, such as wave-particle duality, atomic energy levels, or entanglement, to measure physical, optical, or electromagnetic information from a target. Examples include Rydberg sensors, nitrogen-vacancy magnetometers, HOM (Hong-Ou-Mandel) interferometers, and SQUIDs (Superconducting Quantum Interference Devices). In general, as quantum sensors rely on interrogation at the atomic and photonic level rather than on classical mechanical measurements, these technologies promise advantages over their traditional counterparts in sensitivity, accuracy, and SWaP (Size, Weight, and Power). Conceptually, the use of quantum sensors unlocks the new phenomenology of sensor entanglement. While an ultra-low TRL (Technology Readiness Level) prospect for most sensor types, multi-sensor entanglement is a high risk, high reward strategy with a potential for exquisite sensitivity and SWaP improvements entirely inaccessible to classical sensors.

In March 2022, the National Science and Technology Council Subcommittee on Quantum Information Science released four recommendations for "bringing quantum sensors into fruition," including prioritizing partnerships with end users, conducting feasibility studies, developing broadly applicable components, and streamlining technology transfer. As a trio of organizations that span from basic science researchers to end-use customer, the Space Science and Technology (S&T) Partnership Forum including the National Aeronautics and Space Administration (NASA), National Reconnaissance Office (NRO), and United States Space Force (USSF), is well-positioned to follow these recommendations to implement quantum sensors in space.

The Space S&T Partnership Forum was established in 2015 between NASA, NRO, and USSF to identify synergistic efforts and technologies shared between the agencies, leveraging those synergies to influence science and technology portfolios at each agency in areas deemed pervasive and ready for collaboration. Though the mission scopes of the three partners are distinct, quantum sensors are highly relevant to overlapping areas such as precision Position, Navigation, and Timing (PNT); electromagnetic field sensing; attitude control; communications; and gravimetry. For example, magnetometers based on nitrogen-vacancy centers or SQUIDs may be used for geological magnetic field mapping, mineral or archaeological exploration, or magnetic anomaly detection. Atomic electrometers, such as Rydberg sensors, provide low SWaP Radio Frequency (RF) to THz response with good sensitivity that may be used for communications or electric field sensing.

In March 2023, the Space S&T Partnership Forum kicked off a collaborative quantum sensing effort to accelerate the deployment of space-based quantum sensors for the three partner agencies. Phase 1 of the effort includes

**Figure 13:** Quantum site visit to GSFC, pictured in the Quantum Space Telecommunication Algorithms Research (Q-STAR) Lab.

strategy development to identify quantum sensors with promising potential for space science and operations, as well as the required infrastructures and supporting subsystems. In May 2023, the interagency group convened for a Technical Exchange Meeting (TEM) to discuss quantum technologies of mutual interest. Further decomposition of the quantum technologies of mutual interest in the areas of atomic clocks, atomic interferometers, magnetometers, Rydberg sensors, and superconducting nanowire single-photon detectors (SNSPDs) occurred through online interagency working groups following the TEM. A final report will provide findings and recommendations from the interagency exploration of space-based quantum sensing technologies to inform priorities and collaboration for the Principals of the Space S&T Partnership Forum.

## *OTPS Quantum Sensing Work*

Given the number of ongoing quantum sensing activities across the agency, OTPS believes the agency could benefit from more focused and integrated quantum sensing efforts. Over the past year, OTPS has been analyzing the benefits of quantum sensors to NASA, developing an inventory list of activities related to quantum sensing technologies, and understanding how to assess agency activities. Over the past year, OTPS has been analyzing the benefits of quantum sensors to NASA, developing an inventory list of activities related to quantum sensing technologies, and understanding how to assess agency activities.

### Why This Work Matters

As a think-space for NASA's Administrative Suite, it is OTPS's prerogative to investigate the usefulness and feasibility of integrating new technologies into agency work, such as quantum sensing. Quantum sensing technology has the potential to create new possibilities for science and exploration in space. Through OTPS, there is an opportunity to identify efforts that can be leveraged internally and externally to help the agency better align and focus its own quantum sensing priorities. This effort helps develop clear coordination and strategic prioritization of these activities, adequately linking their applications and potential benefits to NASA's mission.

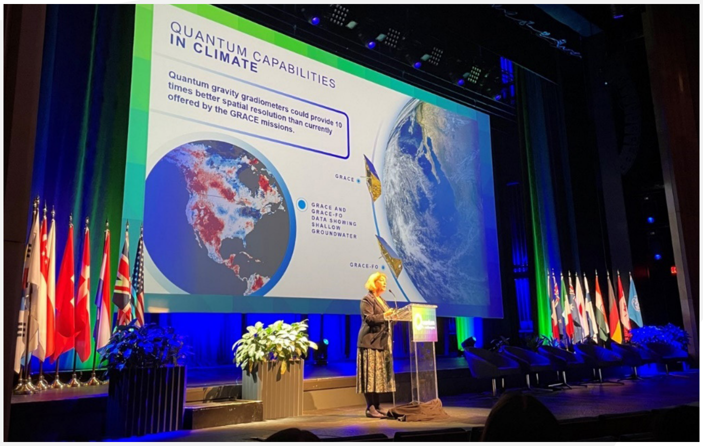



**Figure 14:** Deputy Administrator Pam Melroy delivers Keynote at Quantum World Congress and announces two OTPS studies.

**Figure 15:** NASA quantum computing expert, Eleanor Rieffel (center), testifying to Congress regarding the National Quantum Initiative Act reauthorization, June 7, 2023.

## A Cost and Benefit Analysis of Orbital Debris Remediation

The purpose of the study was to analyze the costs and benefits of cleaning up debris in Earth orbit and to change the way the space community thinks about measuring the hazards of orbital debris. The study included a broad scope of potential methods for cleaning up debris, including methods that move, remove, and reuse debris. Unlike other studies that focus on counting the number of debris over hundreds of years, this study estimated the financial effects to spacecraft operators due to orbital debris on shorter, more relevant timescales. Read the full report titled, "***A Cost and Benefit Analysis of Orbital Debris Remediation.***"

### Why This Work Matters

This study is the first to show that certain methods of cleaning up debris may produce net benefits to spacecraft operators in under a decade. The result of this study is informing NASA decision making regarding R&D investment and policy creation in orbital debris remediation. For example, the insights from this report were used to support the creation of 3 NASA Space Technology Mission Directorate funding solicitations that resulted in 8 awards for early-stage development of debris remediation concepts.

The way you measure a problem influences the way that you think about the problem, the way you decide what to do about the problem, and when to do it. Directly measuring the risks to spacecraft operators in terms of dollars is a better approach than measuring proxies for risk, like the number of pieces of debris in space or the number of conjunctions. Removing cm-sized debris and nudging large debris just-in-time to avoid impending collisions are the most effective remediation methods to reduce risks to operators, leading to net benefits in under a decade. The study team identified an extremely low-cost approach for grabbing and deorbiting large debris; if pursued, this approach may reduce the cost of deorbiting large debris by a factor of 10 compared to currently advertised prices.

**Figure 16:** Jericho Locke (far left) and Tom Colvin (far right) from OTPS participate at the Orbital Debris: Mitigate, Track, or Remediate" panel at the American Institute of Aeronautics and Astronautics (AIAA) Accelerating Space Commerce, Exploration, and New Discovery (ASCEND) conference in October 2023.

## NASA's Technology Scouting

In September 2023, OTPS and other representatives across the agency published a report detailing ways NASA could better research and report on emerging technologies outside the agency. The overall goal of the Technology Scouting project is to develop an approach to conduct effective technology scouting within NASA by first assessing the need for such a capability, evaluating current and recommended approaches, and then developing a strategy to address any weaknesses in the current approach. *Read the full report titled, "Technology Scouting Phase 1 Report."*

### Why This Work Matters

Identifying emerging technologies is critical to a mission-oriented agency such as NASA that is always endeavoring to achieve first-of-a-kind human and scientific exploration goals. While NASA attempts to embrace faster and novel development approaches, there have been several recent examples where the agency has been outpaced in technology research and development, especially by emerging companies. The overall intended outcome of this study is to help develop a more robust technology scouting capability at NASA.

After evaluating a range of organization types, the study identified three basic models for technology scouting: near-term gap filling, needs incubator, and horizon scanning. NASA's current technology scouting practices are generally consistent with those of other government organizations (both U.S. government organizations and international space agencies), but there are differences between how governmental and nongovernmental organizations approach technology scouting, given the customer-centric nature of their work and investments in tools. The study identified three common areas where NASA and other organizations expressed desire to enhance current activities: resource availability, transparency, and integration.

## Wildfire Technology Inventory and Frameworks Examination (In Progress)

OTPS attempted to aggregate agencywide inventory on activity related to the subject of dealing with wildfires. OTPS also identified different frameworks of looking at dealing with the problem including using an "effect-chain": framework for looking at how one deals with wildfires.

### Why This Work Matters

Wildland fires have generated huge costs and other adverse impacts over the past decade. NASA is active in the nationwide effort to mitigate wildfire impacts and is currently working on projects within several Mission Directorates that are relevant to wildfire mitigation. Assessments have highlighted though the need for improved aerial operations in poor visibility areas, continued surveillance for fire detection and tracking, reliable communications, situation awareness and timely access to information. This study aggregates multiple activities to develop an inventory of NASA wildland fire activities. Ongoing work is putting together a novel framework to better address the wildfire situation.

# Chapter 4:
# Select NASA Center Technology Projects

Across the nation, the 10 NASA centers undertake valuable technology research and development to advance NASA's missions and goals. The center chief technologists and deputy center chief technologists facilitating this innovation report to OTPS's agency chief technologist. To highlight center technology innovation, this technology annual features one exciting new NASA technology selected by each CCT on behalf of their home center.

| NASA CENTER | LOCATION | TECHNOLOGY |
|---|---|---|
| • **Ames Research Center (ARC)** | Moffett Field, CA | *Ames Imaging Module (AIM)* |
| • **Armstrong Flight Research Center (AFRC)** | Edwards, CA | *Fiber Optic Sensing System (FOSS) Sensor Suite Supports Aeronautics and Space Applications* |
| • **Glenn Research Center (GRC)** | Cleveland, OH | *Flight Demonstration of Laser Communications Towards Enhanced Security* |
| • **Goddard Space Flight Center (GSFC)** | Greenbelt, MD | *DAVINCI: Maturing a Mission Concept Through Persistent Research and Development* |
| • **Jet Propulsion Laboratory (JPL)*** | Pasadena, CA | *SNSPD Technology Infusion Enables Optical Communications and Future Science Observations* |
| • **Johnson Space Center (JSC)** | Houston, TX | *DNA Sequencing in Space* |
| • **Kennedy Space Center (KSC)** | Merritt Island, FL | *Seed Film—Enabling Astronauts to Plant and Grow Fresh, Nutritious Food for Exploration* |
| • **Langley Research Center (LaRC)** | Hampton, VA | *Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)* |
| • **Marshall Space Flight Center (MSFC)** | Huntsville, AL | *Lunar Thermal Regulation for Mission Sustainability (TheRMiS)* |
| • **Stennis Space Center (SSC)** | MS | *ASTRA—Autonomous Satellite Technology for Real-Time Applications* |

*The Jet Propulsion Laboratory (JPL) is NASA's federally funded research and development center (FFRDC).

# Ames Research Center

## *Ames Imaging Module (AIM)*

A PI was funded twice (FY14 and FY15) by the Center Innovation Fund (CIF) in response to an identified need for a relatively low cost, very small and low powered (CubeSat form factor), scientific–grade camera that was suitable for space operation, not only at Low Earth Orbits but also inter-planetary conditions. While many commercial cameras have flown in space, these cameras are often not suitable for inter-planetary missions due to the increased radiation exposure. Similarly, those cameras that have been designed for inter-planetary travel typically have relatively high resource footprints (particularly power) and come at great cost. With the increasing number of future interplanetary nanosats (e.g., CubeSats) and other small, landed missions (e.g., via Commercial Lunar Landed Services (CLPS) a rugged, small, and relatively low cost camera was needed. The AIM camera is small (6.3 × 6.3 × 6.4 cm), low-mass (<100g + lens), and utilizes a science-grade imager.

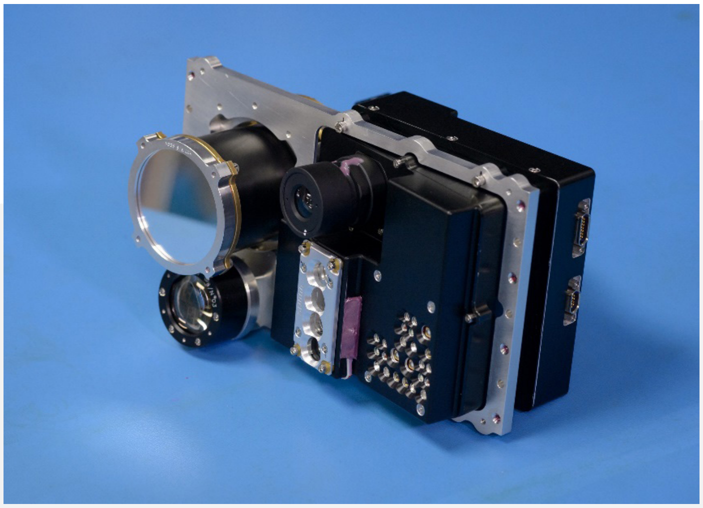


**Figure 17:** The Ames Imaging Module (black enclosure to right in photo above) integrate into the NIRVSS instrument. Credit: NASA Ames Research Center.

What makes AIM very unique is that it was designed from the bottom-up to be radiation tolerant. Consideration of the effects of radiation, both total dose and Single Event Upsets or Latch-ups, were taken in designing the camera, making it very tolerant to radiation even when using commercial parts. Because commercial parts can be used, the camera is up to 100 times less expensive than typical space flight cameras. In addition, the AIM has at its core a very capable FPGA, which allows for a great amount of flexibility in its application and integration into systems. For example, as part of the CIF awards the prototype camera was integrated with a rover with an interface data rate of 115 kbps and a user-selectable set of LED illumination lamps (which the camera controlled). At these slow data rates, on-camera windowing and scaling were required. In another application the camera, capable of data downlink at 10 Mbps, was flown on a sounding rocket illustrating the ability to customize data rates. For this sounding rocket application, onboard auto-exposure was required. In both applications the same camera hardware was used, but specific interfaces and controls were programmed via the FPGA.

Currently the AIM is integrated into the Near InfraRed Volatiles Spectrometer System (NIRVSS) instrument, providing multi-color high-resolution context imaging for the other NIRVSS sensors. NIRVSS is manifested on the CLPS Astrobotic Peregrine Mission-1 lunar lander, currently slated for launch in January 2024. NIRVSS/AIM is also integrated into the Volatiles Investigating Polar Exploration Rover (VIPER) lunar rover mission, scheduled for launch in late 2024. A third version of NIRVSS/AIM has been flight qualified and delivered in-place, awaiting a future manifest via CPLS.

# Armstrong Flight Research Center

## *Fiber Optic Sensing System (FOSS) Sensor Suite Supports Aeronautics and Space Applications*

What began as a research tool to collect aerodynamic data from research aircraft is now solving technical challenges within the agency and beyond. NASA's patented, award-winning Fiber Optic Sensing System (FOSS) technology combines advanced strain sensors and innovative algorithms into a robust package that accurately and cost-effectively monitors a host of critical parameters in real time. It is being widely used throughout NASA to support research projects as varied as investigating next-generation flexible wings, measuring liquid fuel levels, and monitoring strain on spacecraft.

For more than two decades, the FOSS team at NASA's Armstrong Flight Research Center has optimized the technology to refine the infrastructure and speed with which the system collects and transmits data, and the technology's easy-to-integrate elements now complement and add color to existing instrumentation. FOSS has supported numerous flight projects, from the unmanned Ikhana aircraft to Global Observer to the multiutility X-56 research aircraft.

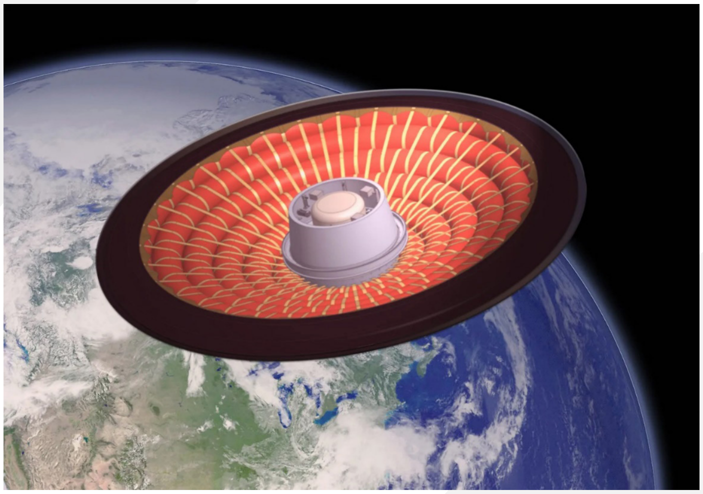


**Figure 18:** NASA Armstrong's Fiber Optic Sensing System (FOSS) collected temperature data on the Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) as it re-entered the atmosphere and landed in the Pacific Ocean on November 10, 2022.

FOSS uses up to a 40-foot, hair-like optical fiber that provides up to 2,000 data points each. The state-of-the-art system processes information every quarter inch along the fiber at rates up to 100 times per second to measure strain, shape deformation, temperature, liquid level, and operational loads.

The sensor suite enables researchers to verify finite element models to a high degree of spatial resolution. It also allows researchers to identify unexpected phenomena in cases where a model is not completely accurate or does not contain enough degrees of specificity. FOSS enables both validation and discovery, making the entire research process more effective and efficient.

In recent years, the FOSS team has pivoted from an aeronautics focus to developing innovations to support space applications. This effort has required taking a new look at how the electronic components are packaged and assembled to meet the demands of a space environment. Potential applications include monitoring the health of spacecraft and measuring levels and temperatures of liquid fuel tanks during spaceflight.

FOSS collected temperature data during the agency's Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) mission. When LOFTID launched in November 2022 aboard a United Launch Alliance Atlas V rocket from California's Vandenberg Space Force Base, it carried 1,400 FOSS sensors on three optic fibers totaling 60 feet in length, placed in a spiral pattern on LOFTID's nose, while the FOSS box was mounted in the vehicle's midsection. FOSS provided a thermal map of the heat LOFTID was subjected to as it re-entered Earth's atmosphere and landed in the Pacific Ocean.

# Glenn Research Center

## *Flight Demonstration of Laser Communications Towards Enhanced Security*

NASA's Glenn Research Center has developed and demonstrated an airborne laser-based communication capability. The muti-year goal of this work is a capability to address introducing quantum key distribution into the National Airspace System. Quantum key distribution can provide encryption for unambiguous, high-bandwidth, point-to-point communications known only between shared parties. Demand for secure communications will grow as the nation's airspace is increasingly populated by uncrewed vehicles. An equally important goal is to explore extending its application to space-based communication architectures.

This work was initiated by Glenn's Quantum Technologies Team (QTech) in 2017. It was supported by the Aeronautics Research Mission Directorate (ARMD) Convergent Aeronautics Solutions (CAS) program. Participation expanded to include NASA's Ames Research Center, the Air Force Research Lab (AFRL), and a Small Business Innovative Research (SBIR) program industry partner. Flight test operations engaged collaborations with the Science Mission Directorate's Earth Sciences Division for critical data transfer experiments, Space Operations Mission Directorate's Space Communication and Navigation (SCaN) demonstrations of High Data Rate, Delay/Fault Tolerant Network (HDTN) concepts, and AFRL Open Mission Systems experiments.

**Figure 19:** 1GRC Airborne Laser Communication Testbed in flight aboard the GRC DHC-6 Twin Otter Aircraft.

Based on an inertially-stabilized, bidirectional, Free-Space Optical Communications system (FSOC) approach, quantum key distribution hardware/software implementation utilizes a single-photon regime to securely generate encryption keys between a flight platform and a symmetric ground station near the GRC Hangar. Utilizing precision laser links between communication nodes, the prototype system maintained Gigabit/second data transfer rate capacity at ranges of 10's of kilometers and at reduced rates out to 100 kilometers in the first flight campaign over Lake Erie in 2019.

A second flight campaign in 2021 integrated upgraded FSOC terminals. Improvements in precision laser pointing led to higher data transfer rates over longer distances and produced a readily deployable gigabit-class airborne laser communication testbed (ALCT) capability for the agency. Results of the system in the weeks-long flight campaign included in-flight high-speed internet connectivity and scientific customer utilization of the system for NASA and AFRL system flight demonstrations.

A third flight campaign in 2024 is supported by SCaN utilizing Glenn's new PC-12 aircraft platform to conduct further development of delay/fault-tolerant (HDTN) laser communication capabilities, and provide flight testing opportunities for NASA and AFRL technology teams.

Glenn's Free Space Optical Communication development provides high-capacity communications for US Airspace Communications, including unambiguous inter-node links, freedom from RF spectrum restrictions, and highly secure communications in the increasingly complex national airspace system.

# Goddard Space Flight Center

## *DAVINCI: Maturing a Mission Concept Through Persistent Research and Development*

DAVINCI, the Deep Atmosphere Venus Investigation of Noble gases, Chemistry and Imaging mission exemplifies how IRAD Internal Research and Development funding, combined with persistent, innovative mission design and maturation, help expand NASA's reach into our solar system and our understanding of worlds beyond.

Buried beneath a smothering carbon dioxide and acid atmosphere devoid of water vapor, Venus's scorched landscape endures 90 times the weight of Earth's atmosphere. At that pressure, amid temperatures hot enough to melt lead, air behaves as much like a liquid as a gas.

Goddard research and development grants contributed to the development of DAVINCI's parachute, window seal, atmosphere probe, a new external antenna design, and other systems necessary to survive Venus's punishing atmosphere. Maturing these particularly challenging technologies beyond NASA's existing capabilities allows the mission to protect its vital organs from the heavy sulfuric clouds, temperature, and pressure while providing safe exposure for sensors and communications.

The team developed half and full-sized prototypes of the capsule to test their seals' ability to withstand Venus's intense atmospheric pressure. From 2008 on, projects for design and mission planning, construction, and development transitioned to testing and further refinements to the capsule and seal designs which continue through today.

**Figure 20:** DAVINCI Principal Investigators Giada Arney, James Garvin, and Stephanie Getty stand with the full-sized model of their atmospheric probe.

While submitting multiple unfunded proposals over the years, the DAVINCI team used research and development funding to address risks and questions raised during proposal evaluations. Each successive project advanced the mission forward toward their ultimate successful bid and selection in 2021.

Even as the mission began incorporating Pre-Phase A funding, further IRAD awards supplemented the team's efforts to refine their seal technologies and the external radio antenna. Additional grants supported testing these technologies under Venus-like conditions: temperatures up to 878°F (470°C) and 93 times Earth's surface atmospheric pressure.

Selected in 2021, DAVINCI will consist of a carrier-relay spacecraft and an atmospheric descent probe. The carrier-relay spacecraft will track motions of the clouds and identify their composition, as well as map regional surface composition by measuring heat from Venus' surface that escapes through its atmosphere. The probe will sample atmospheric chemistry, temperature, pressure, and dynamics every 50-150 meters during descent. It will also take the first high-resolution images of Alpha Regio: an ancient, rugged highland twice the size of Texas. These images will help look for signs of water's influenced on surface rock formation in its distant past, when scientist believe the planet might have been more like Earth.

DAVINCI will be the first NASA-built probe to explore the deepest atmosphere of Venus and the first U.S.-built Venus probe since 1978. NASA Goddard is the principal investigator institution and is working with other NASA centers, businesses, and academic partners.

Deep atmosphere probes are the only way to answer questions about the connections between atmospheric evolution, the existence (or not) of global oceans, and surface-atmosphere chemistry interactions.

Probes which can survive and conduct science in the atmospheres of Venus, Saturn, and Uranus need to demonstrate capabilities on the cutting edge of the technological curve. In addressing these challenges, these technologies can expand NASA's reach into our solar system and inform our understanding of worlds beyond.

# Jet Propulsion Laboratory

## *SNSPD Technology Infusion Enables Optical Communications and Future Science Observations*

Superconducting nanowire single photon detectors (SNSPDs) are the most advanced detectors available for time-resolved single photon counting, from the UV to the longwave infrared (0.1–29 µm). Since 2005, JPL has been a world-leading center for the development of this technology, in collaboration with NIST Boulder and MIT. Our collaboration has recently demonstrated SNSPDs with timing resolution as high as 3 picosecond Full-Width Half-Max (FWHM), pixel counts as high as 400,000 elements (the largest superconducting detector arrays by a factor of 20), and dark count rates below 10-5 counts per second. SNSPDs are a critical technology for ground receivers for deep-space optical communications, as they enable high efficiency time-tagged photon counting at event rates up to a billion counts per second, while maintaining timing resolution below 100 ps. From 2011–2016, JPL engaged in a rapid technology maturation project sponsored by the STMD Game-Changing Development program, which advanced the state of the art from small fiber-coupled devices to large-scale 64-element SNSPD arrays capable of being coupled to large-area telescopes. This technology was then infused into the ground systems for the Lunar Laser Communication Demonstration (2013), the Deep Space Optical Communication project (2023), and the Optical-to-Orion project (planned launch in 2024). The DSOC project, which is the first demonstration of optical communication from interplanetary space, launched successfully aboard the Psyche spacecraft on October 13, 2023, and is currently (as of November 2023) commissioning its first communication links. An SNSPD-based ground receiver at the Palomar 200-inch telescope is a critical element of this ground-breaking laser communication demonstration.

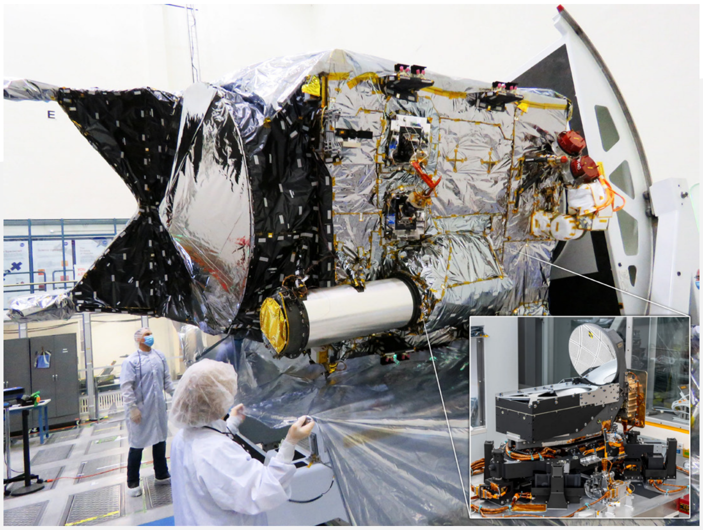


**Figure 21:** DSOC integrated on board Psyche and ready for launch.

In the future, SNSPDs may also be a promising new technology for astrophysical observatories. The low dark count rates, high pixel counts, and high radiation tolerance make SNSPDs a potential technology for the science camera in the Habitable Worlds Observatory, and the infrared SNSPDs close an important technology gap for low-noise single-photon counting detectors from 15–30 µm, beyond the reach of mercury cadmium telluride sensors. Technology development on SNSPDs at JPL has been supported by NASA STMD, NASA SCaN, NASA SMD, JPL internal R&D funding, and reimbursable sponsors (DARPA, DOE, U.S. Government, and industry).

# Johnson Space Center

## *DNA Sequencing in Space*

For nearly two decades, microbial monitoring of the International Space Station (ISS) has relied on culture-dependent methods that require returning samples to Earth for analysis. This method has its limitations, including the inherent delay between initial sampling and ground-based evaluation. In recent years, portable and easy-to-use molecular-based tools, such as the Oxford Nanopore Technologies' MinION sequencer have been validated onboard the ISS.

Starting as a Center-Level Independent Research and Development (IRAD) project in October 2015, a full sample-to-sequencer, DNA extraction and preparation method for the MinION was developed. In 2017, implementing part of this method on Station resulted in the first off-Earth identification of unknown microbes collected and cultured from ISS surfaces. In 2018, a subsequent payload demonstrated the full method, nicknamed "swab-to-sequencer," could eliminate the need to culture the microbes, providing a game-changing solution to real-time microbial profiling onboard the ISS. With the success of these experiments, the MinION sample preparation IRAD project for DNA sequencing evolved to a Medical Operations systems demonstration on orbit called "BioMole."


**Figure 22:** NASA astronaut and Expedition 69 Flight Engineer Jasmin Moghbeli services microbe samples for DNA sequencing aboard the International Space Station.

Validation studies were conducted first through extensive ground-based assessments followed by additional culture-independent verification studies during two NASA Extreme Environment Mission Operations (NEEMO) analog missions. Finally, two crew members conducted four independent swab-to-sequencer experiments onboard the ISS using the same standard protocols. The opportunity for field testing of the method during NEEMO provided substantial insight toward improved packaging and labeling of kits, as well as optimization of crew procedures for application onboard the ISS.

As deep-space exploration will not easily allow for sample returns, the goal of BioMole is to replace current culture-based hardware and the necessary sample return with inflight analysis via DNA sequencing. To that end, the BioMole method has been baselined for Gateway, known as the Microbial Surface Monitor (MSM). BioMole and the future MSM allow for the identification of microbes without the need for culture or sample return and provides near real-time data. This simplified sequencing method is a critical advancement for monitoring crew health in near real-time.

This technology, capable of providing rapid characterization of the environment and human health, is critical to extending human space exploration. The swab-to-sequencer method can be completed entirely in the spaceflight environment and along with on-orbit data analysis, is adaptable to extend beyond environmental microbial profiling and to potentially aid in infectious disease diagnostics to enable human exploration of the Moon and on to Mars.

## Kennedy Space Center

### *Seed Film—Enabling Astronauts to Plant and Grow Fresh, Nutritious Food for Exploration*

As humans have expanded across the continents and the oceans, they always took their crops with them to sustain their journey.  The long-term exploration of space will be no different and will be even more challenging. Space crops can provide nutrients which degrade in the packaged diet, they can alleviate menu fatigue by providing variety, and positively impact behavioral health by providing sensory inputs that maintain Earth connections, but there was no way for astronauts to easily handle and plant seeds in microgravity until NASA developed and tested Seed Film. The Seed Film concept was developed by two NASA scientists working out how to grow microgreens in microgravity. The duo wanted a film that would hold seeds and could be rolled out onto a substrate such that the film would dissolve, leaving behind seeds to germinate and grow.

There are hundreds of food-safe, water-soluble polymers, and one polymer was better than the others with respect to low water content when dry, time to dissolve, thermal properties, mechanical properties, and methods to create film compositions. That polymer was Pullulan.

Pullulan is a food-safe, water-soluble polysaccharide which can be easily altered by adding food-grade glycerol. Glycerol acts as a plasticizing agent in pullulan to make it more flexible. Several compositions were tested to determine processing guidelines and optimize thickness of the films for seeds with the goal to have mechanical properties that enabled handling, sufficient thickness to embed the seed, but also limited excess polymer to reduce dissolved polymer within the growth hardware. Through dozens of iterations and developmental improvements, Seed Film was readied for test on the International Space Station as part of the VEG series of crop growth technology demonstration tests. VEG-03J using red romaine lettuce as the test plant was initiated by astronaut Mike Hopkins on January 4th, 2021. For the first time, astronauts planted space crops in Veggie. Until then all VEGGIE seeds had been planted on Earth. The plants germinated better than three other red romaine plant studies and the plants grew larger than previous experiments. The NASA-developed pullulan seed film technology is expected to enable astronauts to maintain a crop library from which they can choose what crops they would like to grow for nutrition, increased menu variety, and improved behavioral health.

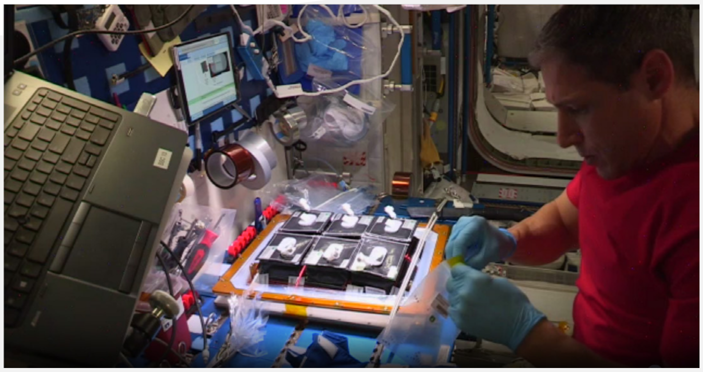


**Figure 23:** Mike Hopkins aboard the International Space Station selects a seed film coupon to crops for the first time in space.

## Langley Research Center

### *Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)*

For destinations with an atmosphere, one of the challenges NASA faces is how to deliver heavy payloads (experiments, equipment, and people) because current rigid aeroshells are constrained by a rocket's shroud size. One answer is an inflatable aeroshell that can be deployed to a scale much larger than the shroud.

A little more than a year ago, a major NASA flight test of exactly this kind of technology came screaming back from space at more than 18,000 miles per hour and reached a peak temperature of about 2,700°F before gently splashing down in the Pacific Ocean, becoming the largest blunt body ever to reenter Earth's atmosphere.

The Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID), which launched Nov. 10, 2022, aboard a United Launch Alliance (ULA) Atlas V rocket, demonstrated inflatable heat shield technology—also known as a Hypersonic Inflatable Aerodynamic Decelerator (HIAD) aeroshell—that will advance NASA's exploration of the unknown in space. This technology could allow larger, more massive spacecraft (and their contents) to safely descend through the atmospheres of celestial bodies such as Earth, Mars, Venus, and even Saturn's moon, Titan.

**Figure 24:** The Low-Earth Orbit Flight Test of an Inflatable Decelerator, or LOFTID, spacecraft is pictured after its atmospheric re-entry test in November 2022.

In October 2023, the LOFTID team held a post-flight analysis assessment of the flight test at NASA's Langley Research Center in Hampton, Virginia. Their verdict? It performed beautifully—almost exactly as modeled.

Due to the success of the tech demo, in July 2023, NASA announced that as part of its Tipping Point program it would ***partner with United Launch Alliance to develop and deliver a larger HIAD aeroshell*** for recovering the company's Vulcan engines from low Earth orbit for reuse.

HIAD technology has been through more than a decade of development, including two smaller scale suborbital flight tests prior to LOFTID. NASA established the HIAD portfolio to manage the technology's potential use with commercial companies and mission applications. NASA is also working to develop a reentry capability for small satellites, as well as aerocapture and a cislunar payload return using HIAD aeroshells.

# Marshall Space Flight Center

## *Lunar Thermal Regulation for Mission Sustainability (TheRMiS)*

The Marshall Space Flight Center (MSFC) has long been a leader in thermal systems for extreme environments, including surviving extremes on the Lunar surface such as the cold Lunar night. However, both Apollo and Artemis generation systems are to date designed only to operate during the Lunar day. An approach to survive the Lunar night, without nuclear devices, leverages a Warm Electronics Box (WEB) that contains all sensitive electronics alongside the battery to maximize heat-sharing between components. The WEB is connected to a radiator via a variable link such that heat flows to the radiator during the warmer daytime but is isolated from the radiator during the colder nighttime.

An Early Career Initiative (ECI) project, Lunar Thermal Regulation for Mission Sustainability (Lunar TheRMiS), was awarded at MSFC in 2020 to continue development of these non-nuclear thermal concepts. Lunar TheRMiS is a design toolkit; a guiding architecture for determining components for the WEB, variable links, and radiators. The toolkit's thermal control components have been developed by MSFC and key partners. Leveraging Small Business and Innovative Research (SBIR) investments, several of these components have been developed in partnership with Advanced Cooling Technology (ACT), tested at MSFC as a part of Lunar TheRMiS, and are currently being infused for enabling extreme thermal system capabilities; all within 3 years from the ECI award to flight.

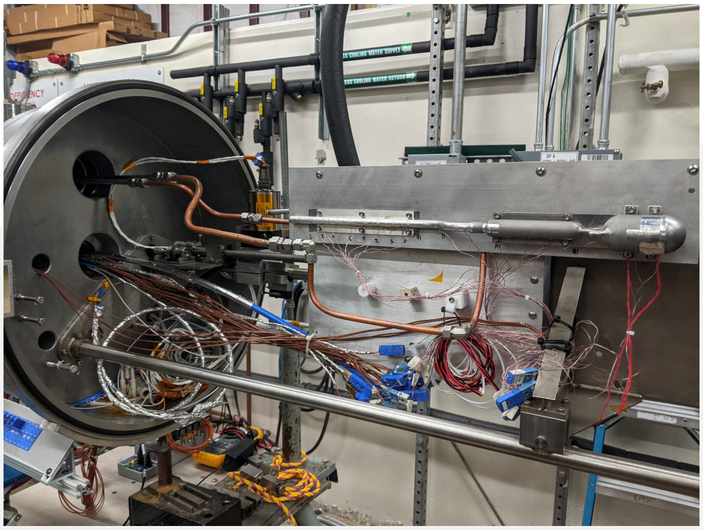


**Figure 25:** Warm-reservoir Variable Conductance Heat Pipe protoflight unit under thermal qualification testing for the Peregrine 1 Lunar lander mission.

An example key technology within the toolkit is a warm-reservoir Variable Conductance Heat Pipe (VCHP). Unlike a traditional VCHP in that it moves the reservoir from the condenser (cold) side to the evaporator (warm) side of the pipe. This "warm" architecture enables tighter thermal control that passively shuts off heat transfer when temperatures drop below a certain threshold. Integrated system design and testing completed at MSFC demonstrated excellent protoflight performance of the warm-reservoir VCHP. The VCHP was later qualified through vibration and thermal vacuum testing for low-risk operational implementation. This VCHP is currently integrated onto Astrobotic's Peregrine 1 Lunar lander for its upcoming flight to the Lunar surface. The mission is manifested for launch in January 2024 and will aide in the understanding of warm-reservoir VCHP performance in the Lunar environment. Lunar surface operations will validate the technology within the Lunar TheRMiS toolkit.

# Stenniss Space Center

## *ASTRA—Autonomous Satellite Technology for Real-Time Applications*

ASTRA is a mission to mature integrated systems health management and autonomous operations of a small satellite. Developed by NASA Stennis Space Center (SSC) and E3S/D2K, ASTRA will autonomously detect anomalies, identify the probable root cause of the anomalies, create strategies to mitigate anomalies, and at the end of the mission, autonomously control the satellite and its primary payload.

The ASTRA mission will provide flight heritage for multiple technologies including the NASA Platform for Autonomous Systems (NPAS), the S-A1760 Venus radiation-characterized Space AI GPGPU, and a NPAS/Space Bus Network bridge to the Core Flight System (cFS) software enabling integration with cFS applications for telemetry and commanding. The mission was enabled by multiple public-private partnerships to develop essential software tools.

**Figure 26:** The flight S-A1760 Venus radiation-characterized Space AI GPGPU that provides high-performance computing capabilities that enable onboard integrated systems health management and autonomous operations.

The ASTRA team partnered with Sidus Space to leverage Sidus' hardware and software development expertise. The ASTRA payload will be hosted on the Sidus Space LizzieSat-1, a proprietary multipurpose satellite bus that integrates custom payloads as rideshares.

The ASTRA team designed, built, and tested ASTRA flight software, and integrated the flight software with the ASTRA Space AI GPGPU. Sidus Space is responsible for integrating the ASTRA hardware on LS-1, as well as for satellite launch, and all satellite mission operations.

The autonomous systems capabilities demonstrated by ASTRA are immediately applicable to multiple Artemis objectives and elements. In this way, the ASTRA partnership with Sidus Space will reduce the time to deploy high-priority capabilities to Artemis missions and reduce risk, program cost, safety issues, and schedule challenges through the successful demonstration of autonomous operations.

# Appendix:
# Biographies of the Current NASA Center Chief Technologists (CCTs) and Deputy Center Chief Technologists (DCCTs)

**Figure 27:** The Ames Research Center in Moffett Field, California.


**Figure 28:** The Armstrong Flight Research Center in Edwards, California.


**Figure 29:** The Glenn Research Center in Cleveland, Ohio.

**Figure 30:** The Goddard Space Flight Center in Greenbelt, Maryland.

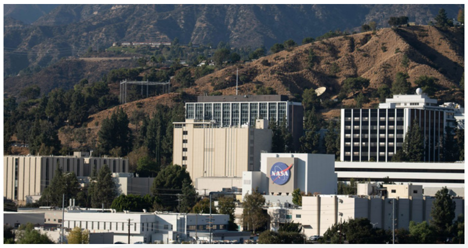


**Figure 31:** The Jet Propulsion Laboratory, in Pasadena, California.

**Figure 32:** The Johnson Space Center in Houston, Texas.

**Figure 33:** The Kennedy Space Center in Merritt Island, Florida.

**Figure 34:** The Langley Research Center in Hampton, Virginia.

**Figure 35:** The Marshall Space Flight Center in Huntsville, Alabama.

**Figure 36:** The Stennis Space Center in Mississippi.

## *Ames Research Center (ARC)*

### Center Chief Technologist:
### Harry Partridge

Email: *harry.partridge@nasa.gov*

Dr. Harry Partridge is the Ames center chief technologist (CCT), and as such identifies, defines, develops, and integrates new and emerging technologies for application to agency and national goals. Dr. Partridge reports to and advises center leadership on matters concerning centerwide technology development and leverage. His duties include representation on the agencywide Center Technology Council (CTC). Dr. Partridge has expertise in chemical physics, computational chemistry, nanotechnology, and entry systems. He was formerly the Deputy Director of the Game Changing Program and the Senior Technical Officer of the Space Technology Mission Directorate. His interest areas include space technology, commercial space, hypersonics, and the Materials Genome Initiative.

### Deputy Center Chief Technologist:
### Jill Bauman

Email: *jill.bauman@nasa.gov*

Dr. Jill Bauman is the Ames deputy center chief technologist (DCCT). Her responsibilities include reviewing the center's new technologies to determine mission critical needs that may be filled by such technologies, initiating and reviewing potential inter-center and external collaborations for low TRL technology investments, and assessing the center's technology portfolio for strategic maturation planning. Dr. Bauman has expertise in atmospheric physics and experience serving as ARC's associate director for science and as the branch chief for systems and project engineering. Dr. Bauman's interest areas include NASA's early-stage concept investments (process and impact) and Earth Science instrumentation.

## Armstrong Flight Research Center (AFRC)


### Center Chief Technologist:
### David Voracek

Email: *david.f.voracek@nasa.gov*

David F. Voracek is the chief technologist at NASA's Armstrong Flight Research Center in Edwards, California. He leads the effort on advocating for innovation, advising on technology strategy, and helping in technology program decisions for early-stage innovation. Mr. Voracek manages the Center Innovation Fund, which supports new and state-of-the-art technological ideas at the center. Mr. Voracek has experience in structural dynamics, systems engineering, and Flight Research. He has held the positions of Chief Engineer for X-53 and Deputy Director of Research and Engineering at AFRC. His main area is advancing Aerospace Technologies through flight, which includes interests in sustainable aviation, AI and machine learning, and Hypersonics.

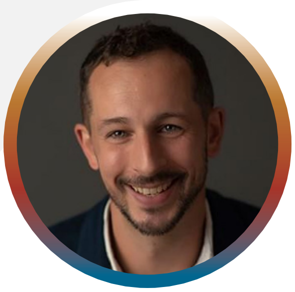
## Glenn Research Center (GRC)


### Center Chief Technologist:
### Kurt Sacksteder

Email: *kurt.sacksteder@nasa.gov*

Dr. Kurt Sacksteder is the chief technologist for the NASA Glenn Research Center (GRC) where he guides early-stage strategic technology investments and partnerships in power, propulsion, communications, materials, and other physical sciences and applications for harsh environments in aviation and spaceflight. Dr. Sacksteder was a founding GRC practitioner of applied research in reduced-gravity combustion and reacting flows. He has served as co-leader of NASA ISRU technology development, Space Technology Research Grants Program Manager, and was Chief of two materials science branches. Dr. Sacksteder's interest areas include combustion and fluid physics in reduce-gravity environments, ISRU for the Moon and Mars, and power and propulsion systems and links to climate remediation.

After over 40 years of distinguished service to NASA, Dr. Kurt Sacksteder, is retiring. In addition to his role as CCT of GRC, Dr. Sacksteder, and before him, Julie Williams-Byrd, served as a dedicated Chair of the Center Technology Council and advisor to the agency chief technologist. The Center Technology Council wishes him all the best in his well-earned retirement and thanks him for his work ethic, technical expertise, and dedicated advocacy for so many early-career professionals while at NASA.



### Deputy Center Chief Technologist (Acting):
### Maxwell Briggs

Email: *maxwell.h.briggs@nasa.gov*

Dr. Maxwell Briggs is the acting deputy chief technologist of the Glenn Research Center, where he focuses on increasing return on investment for early-stage technology developments. Dr. Briggs has experience as an engineer for dynamic power systems including Kilopower, Fission Surface Power, and Advanced Stirling Radioisotope Generator. He has managed the Small Business Innovative Research (SBIR) portfolio for the Aeronautics Research Mission Directorate (ARMD) and developed the SBIR program's Ignite Solicitation, which offers SBIR awards to commercialization-focused companies working on NASA relevant technology. Dr. Briggs's interest areas include space power systems, innovative funding mechanisms for early-stage innovations, and the space economy and infrastructure.

## Goddard Space Flight Center (GSFC)

### Center Chief Technologist:
### Peter Hughes

Email: *peter.m.hughes@nasa.gov*

Peter Hughes serves as chief technologist of the Goddard Space Flight Center. His responsibilities include planning, coordinating, and managing advanced technology-development programs, and advising center leadership on strategies that leverage technology investments to advance NASA's ambitious science and exploration goals. Mr. Hughes, who represents the Goddard Space Flight Center on NASA's Center Technology Council, also manages the center's Internal Research and Development program, and NASA's Center Innovation Fund. Mr. Hughes has experience in computer science and technology management. His interest areas include AI and autonomous systems, digital engineering, space communications and navigation, quantum technologies, and emerging and critical technologies.

### Deputy Center Chief Technologist:
### Bhanu Sood

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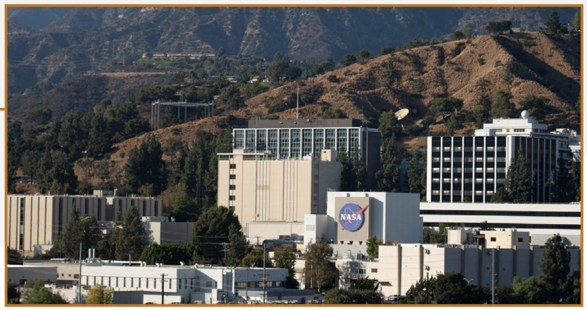
Dr. Bhanu Sood serves as deputy chief technologist of the Goddard Space Flight Center. As the IRAD Program Manager, Dr. Sood ensures that Goddard's diverse investments in technology development are strategically aligned with the agency's science and exploration priorities, innovative, adaptable, and balance risks with an optimized mix of partnerships and collaborations. Dr. Sood leverages his prior experience in developing and deploying large engineering operations, fostering technological solutions based on scientific breakthroughs, technical policy development, and managing supply chain risks in the current role. Dr. Sood's research interests include technology management, STEM workforce development, microelectronics engineering, applications of AI and xR for scientific understanding, and cutting-edge digital engineering approaches.

## *Jet Propulsion Laboratory (JPL)*



### Center Chief Technologist:
### Tom Cwik

Email: *thomas.a.cwik@jpl.nasa.gov*

Dr. Tom Cwik is chief technologist for the Jet Propulsion Laboratory, where he provides strategic leadership for research in advanced technology; manages technology interactions between NASA, JPL, and partners; is responsible for NASA's STMD work at JPL; directs internal investments across the Lab; and guides the infusion of new technology into the Laboratory mission portfolio. Dr. Cwik has experience managing the JPL Space Technology Office, working in technology development in several areas, developing flight systems for several missions, and leading formulation of the NASA Aquarius mission. Dr. Cwik has expertise in electrical engineering and his interest areas include computational engineering and design and leadership of innovative space exploration teams.

### Deputy Center Chief Technologist:
### Charles D. Norton

Email: *charles.d.norton@jpl.nasa.gov*

Dr. Charles D. Norton is the deputy chief technologist at NASA JPL/Caltech responsible for JPL's technology strategic planning, research, and infusion into flight missions. He has led and performed research spanning high-performance computing, advanced information systems technology, and small satellite science and technology mission development. Dr. Norton has expertise in electrical engineering and computational science, having developed and managed multiple SmallSat flight projects for NASA. He has co-authored numerous National Academies reports on remote sensing with small satellites and is a recipient of numerous awards for new technology and innovation, including the JPL Lew Allen Award, NASA Exceptional Service Medal, and the NASA Outstanding Public Leadership Medal.

## Johnson Space Center (JSC)

### Center Chief Technologist:
### Nicholas Skytland

Email: *nicholas.g.skytland@nasa.gov*

Nicholas Skytland is the center chief technologist at the Johnson Space Center (JSC) and Director of the Business Development and Technology Integration Office, where he is focused on helping NASA return to the Moon through open innovation, technology development, technology transfer and strategic partnerships. Mr. Skytland has experience in crew training, space suit design, EVA physiology research and development, as well as experience leading numerous transformation and modernization initiatives. His focus is on helping usher in the future of human spaceflight. Mr. Skytland's interest areas include early-stage technology opportunities and advancement, early career development, technology infusion and partnerships, open innovation, digital transformation, and AI and machine learning.

### Deputy Center Chief Technologist:
### Ronnie Clayton

Email: *ronald.g.clayton@nasa.gov*

Ronald Clayton is the deputy center chief technologist at NASA's Johnson Space Center, where he advises center leadership on matters concerning research and technology development. His responsibilities also include assisting the center chief technologist in providing an integrated approach for strategically aligning the center's technology development and infusion efforts with the agency's future programs and missions. Mr. Clayton has experience in systems engineering and integration and was an avionics integration engineer for the Space Shuttle Program. Mr. Clayton's expertise includes electrical and electronics engineering. His interest areas include early-stage technology opportunities and early career development, technology infusion and partnerships, open innovation, and digital transformation.

## *Kennedy Space Center (KSC)*

### Center Chief Technologist:
### Tim Griffin

Email: *timothy.p.griffin@nasa.gov*

Dr. Timothy Griffin is the center chief technologist of the Kennedy Space Center. His responsibilities include implementing KSC's Strategic Technology Investment Plan and providing strategic advice to ensure KCS work aligns with agency needs and priorities, capitalizes on KSC areas of strength, and ensures valuable research and technology investments. Dr. Griffin has experience in centerwide technical leadership for the planning, management, and evaluation of a comprehensive advanced technology program to meet KSC's mission responsibilities. He is an analytical chemistry expert and has interests in the miniaturization and ruggedization of mass spectrometers and their interfaces and analytical chemistry focusing on new methods for monitoring compounds of interest in unique situations.

### Deputy Center Chief Technologist:
### Kelvin Ruiz

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Kelvin Ruiz is the deputy center chief technologist at NASA's Kennedy Space Center. As DCCT, he supports the center chief technologist on matters concerning centerwide technology development and workforce innovation while documenting, demonstrating, and communicating the societal impact of KSC's technology accomplishments. Prior to becoming KCS's DCCT, Mr. Ruiz was senior electronics engineer for the Space Shuttle Program and served as senior technologist and Science Mission Directorate liaison for the agency's Office of the Chief Technologist. Mr. Ruiz has expertise in electrical, electronics, and industrial engineering and has interests in embedded electronics, avionics, and software; ISRU technologies; SmallSats/CubeSats; and technology development solicitations and partnerships.

## *Langley Research Center (LaRC)*

### Center Chief Technologist (Acting):
### **Phillip A. Williams**

Email: *phillip.a.williams@nasa.gov*

Dr. Phillip Williams is the acting center chief technologist at Langley Research Center, providing technical leadership at LaRC for the planning, management, and evaluation of comprehensive advanced centerwide technology development activities to meet Langley's vision and mission responsibilities across aeronautics, science, and space exploration. Prior to becoming LaRC's Deputy and then Acting CCT, Dr. Williams held positions including research physicist, acting assistant branch head, and senior systems analyst at Langley. Dr. Williams has expertise in physics and his interests include structures and materials, nanotechnology, microscopy and molecular spectrology, space mission and system analysis, technology and capability assessment and integration, and in-space assembly.

### Deputy Center Chief Technologist (Acting):
### **Ali Omar**

Email: *omar.a.ali@nasa.gov*

Dr. Ali Omar is the acting deputy center chief technologist at Langley Research Center, supporting the center chief technologist in overseeing comprehensive advanced technology development activities to meet Langley's vision and mission responsibilities. Dr. Omar was previously the Acting deputy director of the Science Directorate and head of the Lidar Science Branch at Langley. He has held leadership positions at AGU, AMS, and AAAS. His expertise is in aerospace, civil engineering, and atmospheric/Earth science. Dr. Omar's interests include developing space-based remote sensors for Earth and other planets, and maturing algorithms to maximize information content from space-based sensors, and miniaturization of active (radar/lidar) sensors.

## *Marshall Space Flight Center (MSFC)*

### Center Chief Technologist:
### John Dankanich

Email: *john.dankanich@nasa.gov*

John Dankanich is the Marshall Space Flight Center chief technologist and NASA In-Space Transportation Capability Lead. Mr. Dankanich's responsibilities include fostering relationships and guiding investments for technology development for NASA's future mission needs. His prior experience includes serving on the steering committee of the Small Body Assessment Group for the NASA Advisory Council Planetary Science Subcommittee and being the founding Chair of the AIAA Committee on Standards for Electric Propulsion Testing. Mr. Dankanich has expertise in aeronautics and astronautics and specific expertise in technology development, propulsion testing and qualification, low-thrust trajectory optimization, mission design, and planetary defense. His interest areas include propulsion technology development and testing and mission design and trajectory optimization.

### Deputy Center Chief Technologist:
### John Carr

Email: *john.a.carr@nasa.gov*

Dr. John Carr serves as the deputy center chief technologist of the Marshall Space Flight Center. His responsibilities include championing innovation at NASA, working with senior center leaders to build and execute technology development strategy, and managing technology development and infusion plans. Prior to serving as the deputy center chief technologist of MSFC, Dr. Carr was an electrical power engineer at the center and the principal investigator of the Thin-Film Solar Array Development (LISA-T) project. Dr. Carr's expertise is in electrical and electronics engineering and his interests include gossamer technologies including solar sails, thin-film solar arrays, printed electronics, and power systems.

## *Stennis Space Center (SSC)*

### Center Chief Technologist:
### Anne Peek

Email: *anne.h.peek@nasa.gov*

Anne Peek serves as center chief technologist of the Stennis Space Center, a position she has held since January 2022. Previously, Ms. Peek held leadership positions in applied sciences, remote sensing, environmental management, and technology development. At Stennis, she had prior experience serving as Chief of Staff, Legislative Affairs Officer, and Associate Director of the Project Directorate. She was also a NASA legislative fellow for a U.S. senator and Communications Officer for the Associate Administrator for Exploration Systems at NASA HQ. Her expertise includes science and technology policy, biology, and environmental microbiology. Ms. Peek's interest areas include propulsion technology development and testing, mission design, and trajectory optimization.

# CTC: In Special Recognition

## *Langley Research Center (LaRC)*

### LaRC Center Chief Technologist:
### Julie Williams-Byrd

OTPS would like to recognize Julie Williams-Byrd for her service as the Center Technology Council chair through April of 2023. Julie Williams-Byrd was the center chief technologist at Langley Research Center (LaRC). She provided leadership and technical expertise to center senior leaders regarding technology development and maturation of innovative, game-changing, early-stage technologies that meet agency and LaRC vision and enable missions across aeronautics, space exploration and science. Mrs. Williams-Byrd is currently on a developmental detail as Acting Deputy Director of the Systems Analysis and Concepts Directorate. Prior to becoming LaRC's center chief technologist, Mrs. Williams-Byrd held positions including senior systems analyst and electro-optics engineer for research and development of solid-state lasers for LIDAR atmospheric sensing instruments at LaRC.

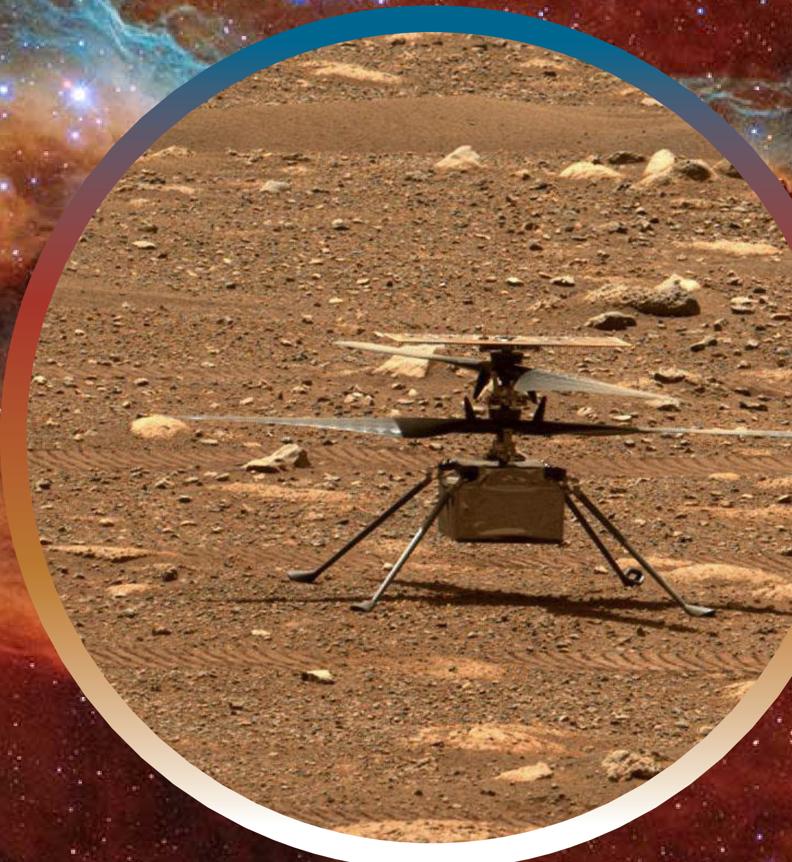

**Figure 37:** NASA's Ingenuity helicopter on the surface of the planet Mars.

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