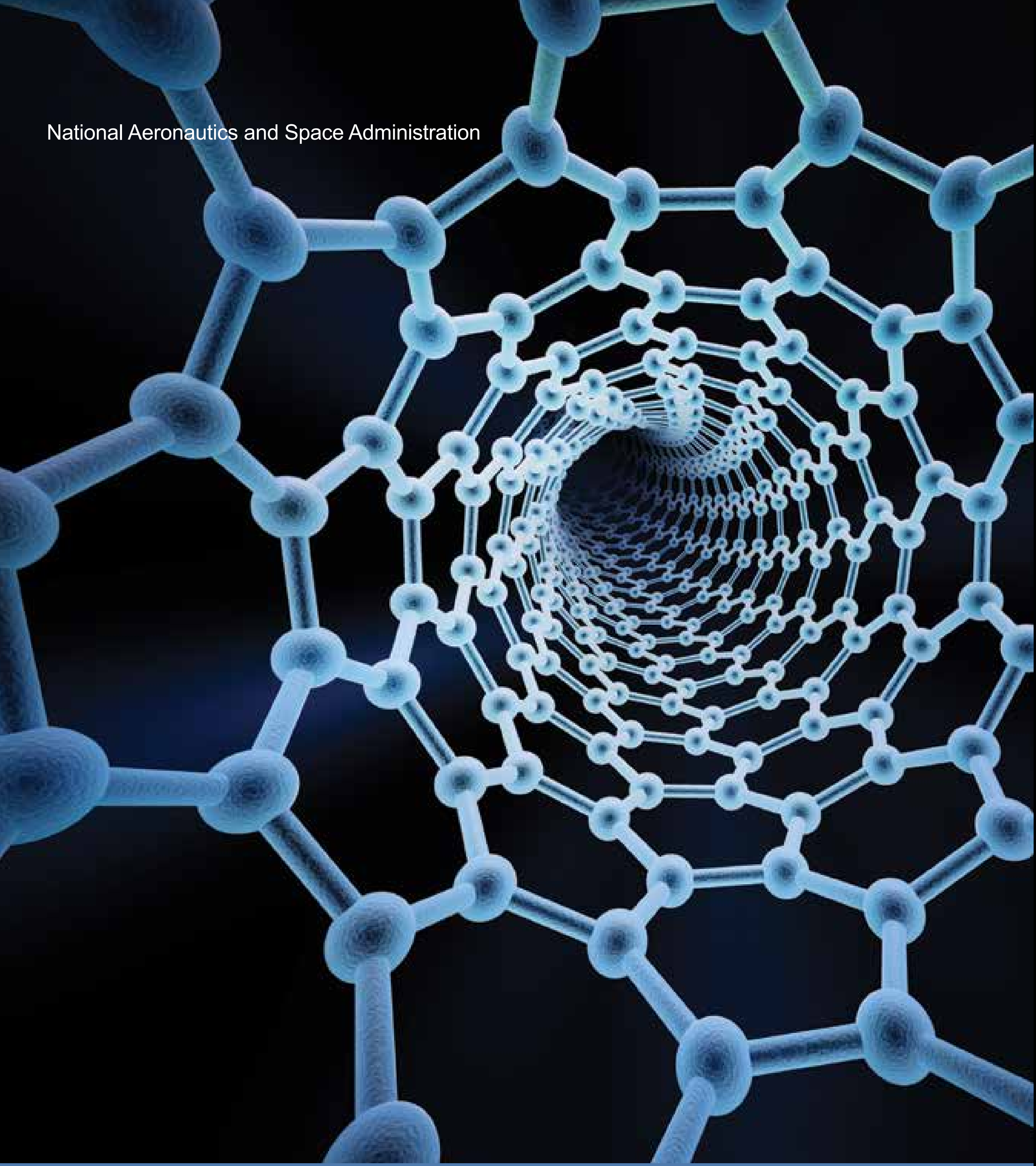
National Aeronautics and Space Administration



GSFC NEWS

tech transfer

Materials Science

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Nona Cheeks

[FROM THE *Chief*

From the Chief

If you stop to think about the occasion for this magazine, the activity of *technology transfer,* there are two fundamental components represented by the conjoined phrase. First, the element of "technology," which deals with the material conditions of research, discovery, innovation, and exploration; and second, the "transfer" of that technology through the appropriate channels of development and commercialization. In essence, technology transfer describes the coming together of things and people to make a common bond, interdependent, requiring the skills of multiple parties working in collaboration, and the craft of seeing beyond the limits of the laboratory.

NASA Goddard is proud to provide a rich setting and charged atmosphere for this important work. This issue's focus on Materials Science makes clear the commitment to technology transfer that our scientists, engineers, managers, and administration uphold. The focus is never on technology alone; without the dedicated people who bring life to the projects described within, there would certainly be no occasion at all to celebrate the work we do together at Goddard Space Flight Center.

When dealing with the extremities of knowledge and what is possible to measure at the edge of technological capacity, we must often set our sights on the parts that eventually add up to a whole new potential. That is exactly what you will read about in this issue of *Tech Transfer News*. A trio of exciting materials advances, with numerous sub-developments, will show why NASA Goddard is at the forefront of space exploration technologies. Starting with graphene, a "wonder material" with a substantial commercial outlook, you will encounter properties and performance advantages that point toward the next generation of optics and sensors and unmanned spacecraft. Graphene is a perfect example of how materials on the nano-scale can have an impact of grand proportion.

Moving on to innovations in coatings technologies, two distinct projects demonstrate the profound advantages of sprayable materials that will cut time and costs from spaceflight missions. Both technology groups were designed with mission safety and success in mind: the Lotus Coating, which uses the "lotus effect" found in nature to simulate an ultra-hydrophobic and self-cleaning nano-texture for dust mitigation; and a Molecular Adsorber Coating, an advanced solution for adsorbing dangerous outgassing that also acts as thermal control for sensitive instruments. These coating technologies can help protect future missions, contributing to safe travel for spacecraft and their precious cargo.

Stopping to think again about the work that makes this magazine possible, I encourage you to share in the satisfaction of a SBIR/STTR success story, learn about Goddard's ITPO outreach and networking efforts, and get to know some of our determined scientists and engineers. You will see in these pages the productive connections between technology and people that enable material innovations to have consequences well beyond the reach of our earthly home.

Nona Cheeks
Chief, Innovative Technology Partnerships Office (Code 504)
NASA Goddard

[MATERIALS SCIENCE *at NASA Goddard*

Materials Science

Materials science has long been established as a critical field in new and emerging technology. With applications in every sector of research and industry, advances in materials science impact society in ways both large and small, each contributing to a smarter, stronger, and more efficient planet. Fittingly, NASA Goddard is at the forefront of Research & Development that will serve applications in terrestrial and extra-terrestrial environments. Goddard's Materials team is busy developing the next generation of technologies that will serve missions with a broader reach in space travel and discovery, along with commercial applications closer to home that include pharmaceuticals, green technology, and transportation.

This issue of *Tech Transfer News* will feature an array of exciting technologies focused on three primary materials advances: Graphene, Lotus Coatings, and Molecular Adsorber Coatings. In addition to interviews with some of NASA Goddard's foremost experts working in this arena, this issue will explore a range of potential applications for these materials-based technologies, including NASA mission-specific applications and commercial applications pertaining to technology transfer opportunities. We hope to highlight the substantial viability of these innovative materials and place their unique R&D programs in the context of NASA Goddard's continuing excellence and leadership in space science.

Working on the nano-scale, innovating based on natural designs, and disrupting the status quo, Goddard's advances in materials science demonstrate the breadth and ingenuity of its researchers, engineers, and program managers. The passion and commitment to serving the mission of Goddard Space Flight Center is articulated directly by the interviews in this issue, and is clearly discernable from the disclosures, patents, outreach, and networking represented in the following pages. The technologies showcase not only the future of space science and exploration, but also confirm NASA Goddard Space Flight Center's ongoing success in government-sponsored R&D, technology transfer, and commercialization.

Goddard technologist Mahmooda Sultana is investigating new applications for graphene, a trailblazing technology with unique physical characteristics that make it ideal for spaceflight and commercial use..

—PHOTO BY NASA

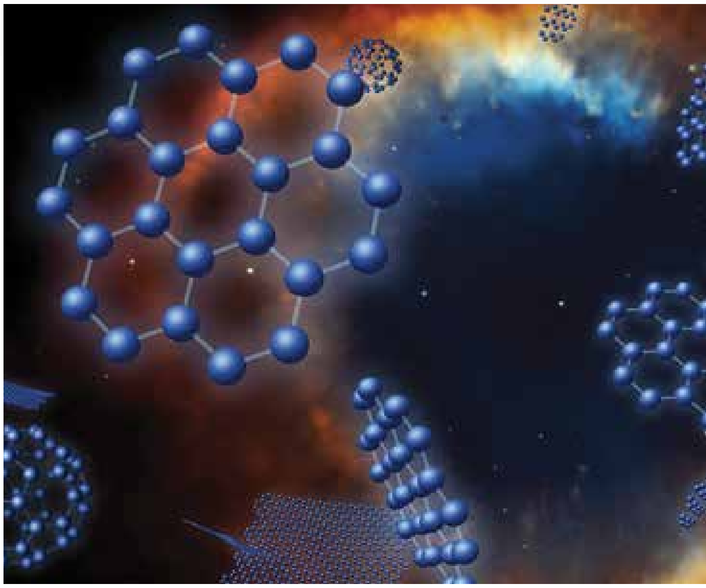
[MATERIALS *Spotlight*

Materials Spotlight

This issue highlights three primary technology areas, all related to advanced materials science: Graphene, Lotus Coatings, and Molecular Adsorber Coatings. Each technology has a range of exciting applications, both within space science and commercial applications with promising technology transfer opportunities. Before discussing applications, this section will present the materials' qualities and performance specifications to provide an overview of the R&D conducted at the NASA Goddard Space Flight Center.

Graphene

Described by its developers as a "wonder material," graphene exhibits remarkable properties of strength, conductivity, and transparency. This unique combination of performance specifications makes it an ideal ultra-thin material for a wide range of applications. In a single atomic layer, which can be achieved using low-pressure chemical vapor deposition, it has shown high conductivity for electron mobility, while also maintaining 95% transparency. This almost perfect transparency is contrasted with 85% transparency in current Indium-Tin-oxide (ITO) electrodes that are widely used in NASA flight missions. Graphene electrodes also demonstrate high transparency in the UV region, achieving 80% quantum efficiency compared to 10-20% efficiency in current silicon-based detectors. These qualities are augmented by graphene's strength and structural toughness, enabling high performance in extreme conditions, especially when exposed to severe radiation. This overall robustness, combined with its advanced properties of conductivity and transparency, make graphene a clear candidate for this Materials Spotlight.



An artist's concept of graphene, buckyballs and C70 superimposed on an image of the Helix planetary nebula, a puffed-out cloud of material expelled by a dying star.

—PHOTO BY NASA

Lotus Coating

It's no secret that nature has served as a source of inspiration for art and science throughout the millennia of human progress. In particular, the lotus plant (*Nelumbo nucifera*), which has been used as a spiritual symbol in Buddhism, is now being used as a model for an extremely hydrophobic dust mitigation coating. The unique structural and chemical properties of the lotus plant, known in nature as "the lotus effect," make it ideal for anti-contamination and self-cleaning purposes; because of these properties, drops of water on a lotus leaf completely clean the surface, removing dirt and other materials. Simulated into a nano-texture coating, the same properties can be achieved on different materials such as glass, ceramic, and metal. The Lotus Coating—which can be composed of silica, zinc oxide, other oxides,

Nature's "lotus effect" is simulated by NASA Goddard Materials experts to achieve an ultra-hydrophobic and self-cleaning dust mitigation coating.

—PHOTO BY NASA

and mixtures and layers—is ultra-hydrophobic and self-cleaning, lightweight, and cost effective. Its reduced surface area, due to the lotus-like structure, contributes to the self-cleaning property while also providing excellent dust mitigation. Additionally, the Lotus Coating has demonstrated excellent stability and resistance to ionizing and displacement radiations. A lotus flower symbolizes the soul's purity, as it blossoms from humble beginnings in the mud. NASA Goddard's Lotus Coating, simulating the unique properties of this plant, offers a purely innovative solution to mitigating dust and protecting sensitive materials in extreme conditions.

Molecular Adsorber Coating

Our final Materials Spotlight focuses on another coating technology designed to protect mission-sensitive instruments and equipment. Addressing the problem of outgassed molecular effluent emanating from potting compounds, epoxies, tapes, lubricants, and other spacecraft materials—which can impair and potentially degrade performance of optical surfaces, thermal control surfaces, solar arrays, electronics, and detectors—Goddard Space Flight Center has developed a zeolite-based sprayable molecular adsorber coating to replace the current solution of ceramic pucks that have significant size and weight limitations. Since both size and weight directly contribute to cost in space flight applications, a lightweight, highly adsorbtive coating can offer significant advantages. In addition to the zeolite coating's increased adsorbtive capacity—up to five times greater than previously developed coating slurries—this new coating can also be applied easily with a spray technique, thereby allowing a greater diversity of material substrates. The formulation is effective on aluminum, stainless steel, or other metals that can accept silicate-based coatings. Along with its mitigation of contaminant outgassing, the coating can serve as a thermal control coating for sensitive instruments. By eliminating the need for adsorber pucks, the coating protects mission objectives without using any mounting and supporting hardware, which impact mass allocation, design, and testing schedules, factors that contribute to overall cost requirements. Such a coating also eliminates the need for electronic box bake-outs, another cost driver. The coating has been developed in conjunction with high surface area systems, such as velvets or fiber mats, which allow the coating to increase its adsorbtive capacity and dissipate electronic charge by maintaining conductivity. This dual advantage of adsorbing outgassing and prohibiting electrostatic discharge events through application with conductive, high surface area systems makes the zeolite coating far more flexible and scalable than the current ceramic pucks. A further innovation, developing the coating into adsorbent paints, improves efficiency in the spray process, increases the ability of the coating to be used on multiple substrates (including flexible surfaces), and allows color customization for specific applications.

Goddard technologist Nithin Abraham, a member of the team that has developed a low-cost, low-mass technique for protecting sensitive spacecraft components from outgassed contaminants, studies a paint sample in her laboratory.

—PHOTO BY NASA

[APPLICATIONS *Overview*

Applications Overview

This section will discuss both NASA mission-specific and broader commercial applications for Graphene, Lotus Coating, and Molecular Adsorber Coating technologies. While Goddard scientists and engineers work hard to advance the field of their expertise within the needs of Goddard Space Flight Center, the nature of R&D in today's funding environment ensures that project managers and lab supervisors are always thinking about potential technology transfer opportunities and commercialization potential. It is a mark of success for NASA Goddard and the Innovative Technology Partnerships Office that the following applications have been identified by those closest to the technologies in this issue.

Engineers prepare and install the Microshutter Array simulator onto the NIRSpec Engineering Test Unit.
—PHOTO BY NASA

Graphene (GSC-16148-1, GSC-16335-1, GSC-16423-1, GSC-16560-1, GSC-16813-1)

The combination of high conductivity and transparency properties makes graphene an ideal electrode material for microshutter (GSC-16148-1, GSC-16335-1) arrays. Graphene offers cost and performance advantages over current Indium-Tin-oxide (ITO) electrodes, which have limited transparency and are getting more expensive in recent years. Microshutter arrays play a critical role in optics for the James Webb Telescope and other missions, and according to Principal Investigator, Harvey Moseley, "The microshutters are a remarkable engineering feat that will have applications both in space and on the ground, even outside of astronomy in biotechnology, medicine and communications."[1] The microshutters are programmable for multi-object sensing capabilities, and with improved performance made possible using graphene transparent conductive electrodes, even the sky is not the limit for this advanced technology integration.

Staying with optical applications, graphene's high electron mobility and transparency also make it an ideal material for Schottky photodiodes (GSC-16423-1) in UV detectors. Graphene Gallium Nitride (GaN) Schottky diodes have the potential to reach record total quantum efficiency of 80%, compared to current levels of silicon-based detectors that have 10-20% total quantum efficiency in the UV region. This considerable performance advantage is made possible by the extreme transparency of single-layer graphene, 40% greater than its current platinum counterpart (90% vs. 50%). With UV detectors of such superior performance, future space missions relevant to earth science, planetary science, and heliophysics will benefit enormously.

1 NASA James Webb Telescope, "Microshutters," http://www.webb.nasa.gov/microshutters.html. Accessed July 7, 2014.

Cryogen and the lightweight cryotanks that store them are used in many NASA missions. If tanks cannot achieve a sufficiently low leak rate, however, exposure to cryogens can compromise mission integrity. In addition to graphene's extraordinary electro-optical qualities, it has also demonstrated impermeability to all gasses and liquids (except for water), and therefore could make an excellent cryotank barrier layer (GSC-16560-1)—ultrathin, lightweight, cost effective—for future missions. By reducing the mass of cryotanks while increasing performance, both time and money is saved in weight allocations and testing schedules. Graphene and subsequent chemical vapor deposition methods exhibit a conformal nature for easy uniform coating, achieved with an inherent structural toughness that can also add value. Overall, the material is so stable at cryo temperatures that it seems an obvious candidate for this application.

Graphene's ultrathin properties and ability to be synthesized with a selected range of pore size makes it an exciting material for environmental applications, namely air filters (GSC-16813-1). As one of the largest environmental concerns facing both developed and developing nations, air quality poses a severe threat to global health. Graphene and graphene derivatives such as graphene oxide can provide effective and inexpensive solutions to air filter technologies, and can be engineered to specific pore sizes from nanometers to microns between crystal grains, depending on the particulate and hazardous chemical requirements for air filters. Such graphene-based air filters could be used in home, office, transportation, manufacturing, mining, and a wide range of other applications. Exposure to air pollution can contribute to debilitating lung diseases, including pneumoconiosis, chronic obstructive pulmonary disease, mesothelioma, lung cancer, and most commonly asthma. A simple, affordable solution to this severe environmental and health challenge could be extraordinarily successful on a commercial scale.

If graphene-based air filters could have significant impact on environmental remediation and global health concerns, it could have an equally significant impact on mobile electronics. Graphene is currently being developed for use in touchscreens, with anticipation that it could become the leading replacement for Indium-Tin oxide (ITO), which according to a recent article on Bloomberg BusinessWeek, "is too brittle for bendable displays and isn't durable or effective enough for devices with screens bigger than about 10 inches."[2] Graphene touchscreens could potentially revolutionize the emerging market for wearable computers; and there is already heavy activity from the commercial-giant Samsung in patent applications related to graphene. "Stretched across the surface of a phone or a tablet, graphene can turn any device into a touchscreen—think of it as a high-tech version of cling wrap," the article states, and goes on to announce, "Graphene's other attributes, including the ability to conduct electricity about 100 times faster than silicon, mean it's likely to also wind up in memory chips and TVs—products in which Samsung is already dominant." [3]

Lotus Coating (GSC-15819-1, GSC-16117-1, GSC-17004-1)

NASA Goddard's Lotus Coating was developed for the primary application of dust mitigation (GSC-15819-1). The unique natural properties of the lotus plant make it extremely hydrophobic and self-cleaning. As a result of this "lotus effect" found in nature, the leaves of the plant also have anti-contamination properties that allow the lotus plant to thrive in harsh environments. This combination of properties—hydrophobic, self-cleaning, and anti-contamination—have been simulated to create an effective and adaptable dust mitigation coating for space missions. The problem of dust accumulation on spacecraft, instruments, and astronaut EVA suits (including visors) has been well documented, and future Lunar, Martian, and asteroidal missions risk compromised performance if sensitive equipment is damaged by dust. By reducing surface energy and the amount of surface area needed for attachment, this nano-texture coating sheds dust particles without interfering with the substrate material. If dust does accumulate on the surface, the coating is easily cleaned using air, water, brush, vacuum, and/or vibration. The Lotus Coating is highly stable and robust, making it optimal for long-term performance in harsh conditions. Preliminary R&D by the Materials team indicates it to be an advantageous technology for mitigating dust on

2 "The Race to Develop Graphene," by Jungah Lee. Bloomberg BusinessWeek, http://www.businessweek.com/articles/2014-05-29/samsung-leads-in-graphene-patent-applications. Accessed July 7, 2014.

3 Ibid.

spacecraft surfaces, thermal control surfaces, solar array panels (and other optical surfaces), habitation airlock walls (and other habitation areas), astronaut EVA suits and tools, and astronaut visors.

The combination of properties that both minimize particulate build-up and facilitate cleaning of particulate contamination, along with its ultra-hydrophobic nature, give the Lotus Coating obvious advantages in commercial applications such as windows on buildings and automotive windshields. Having demonstrated strong performance on multiple substrates, the Lotus Coating could significantly improve dust and dirt mitigation on glass surfaces. This could lead to significant time and cost savings for window cleaning on commercial buildings; and it could also lead to improved safety on automotive windshields, which is always a major driver for automobile manufacturers.

Wanda Peters, Principal Investigator for NASA's Lotus Coating research and Lead of Goddard's Coatings Engineering Group, holds some material with the lotus coating on it.

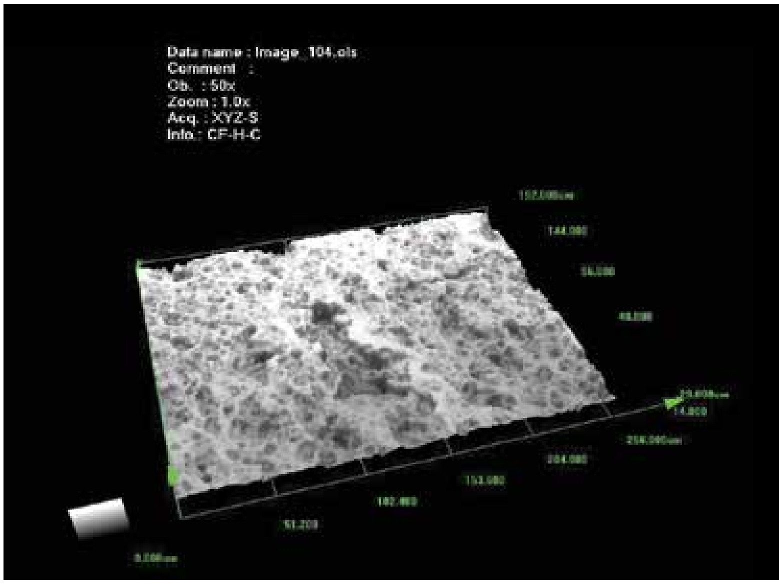
—PHOTO BY NASA

In collaboration with International Photonics Consultants/Northrop Grumman Aerospace Systems, the NASA Goddard Materials team is working to on a testing program on the International Space Station for the Lotus Biocide Coating (GSC-16117-1). This coating is being developed particularly to address bacterial and particulate concerns during long-duration space exploration in enclosed environments. Issues with air revitalization and waste management necessitate antimicrobial and anti-contamination solutions for human habitation areas. A Lotus Coating with the added advantages of biocide properties utilizing nano-sized semiconductor semimetal oxides to neutralize biological pathogens and toxic chemicals could provide a thin and lightweight technology to improve health and safety aboard spacecraft and space stations. The Lotus Biocide Coating also maintains the performance advantage of stability in harsh environments, and will not degrade with time or exposure to radiation or biological/chemical agents. In addition to space exploration, the Lotus Biocide Coating also has promising applications in hospitals, pharmaceutical manufacturing, chemical processing and manufacturing, and other commercial industries with high risk of microbial contamination.

Since technology transfer opportunities for the Lotus Coating are ultimately about material properties, application specifications, and market drivers, we can identify a range of commercial niches that would benefit from an advanced coating engineered to protect surfaces of various substrates with high performance requirements. Applications in aerospace (airplane and engine de-icing), boat production (protective hull coatings), textiles (hazardous clothing), and alternative energy (solar arrays, wind turbines, etc.) are all legitimate leads for this innovative nanomaterial.

Molecular Adsorber Coating (GSC-16105-1, GSC- 16156-1, GSC-17075-1)

The Molecular Adsorber Coating (GSC-16105-1) was developed to address the problem of outgassing on space flight missions, which can damage sensitive instruments and shorten the life and performance of critical equipment such as optical surfaces, solar arrays, thermal control systems, electronics, and detectors. The sprayable zeolite-based adsorber coating can replace current ceramic pucks that take up valuable real estate, and more importantly, add extra weight to limited mission requirements. This extra weight also adds cost due to an increased testing schedule, which translates to both time and money for the mission. The ability of the coating to control adverse on-orbit molecular contamination will ensure optimal performance over longer durations, thereby improving mission success while eliminating the need for superfluous mounting hardware used with the cordierite adsorber pucks. Even though the pucks are relatively inexpensive to fabricate, the sheer amount needed to remediate offgassing—for example, there are over 60 pucks inside the Hubble Space Telescope—combined with the cost and severe inconvenience of supporting their use, creates ample opportunity for an innovative replacement material. The ease of spray application, along with the reduction to mass allocation, hardware design, integration, and test schedule gives the Molecular Adsorber Coating a clear advantage over the existing technology.



This is a close-up view of the highly porous, sprayable coating that Goddard technologists created to attract and then trap outgassed contaminants that harm spacecraft components.
—PHOTO BY NASA

Molecular outgassing is also an issue in aerospace and automotive manufacturing. Contamination can effect sensitive instrumentation and also pose health risks for passengers. According to an article discussing how adsorber coatings can kill the new car smell, "The problem is, that smell - or outgases as NASA calls them -- is generated by chemicals and solvents used to manufacture dashboards, car seats, carpeting and other components that are not particularly good to breathe and as NASA points out, some can be detrimental to sensitive satellite instruments containing the same ingredients."[4] With two drivers such as degraded performance of critical systems and potential safety hazards, there is definite commercial potential for an adsorber coating that can eliminate the need for other solutions that impact the design and integration of manufacturing components. The advantage of a sprayable coating is its easy application and minimal requirements for adoption.

The adsorber coating has also been demonstrated on conductive fiber velvet mats, which allow for dissipation of charge buildup and provide a greater adsorbtive capacity by increasing the available surface area of the coating (GSC-16156-1). In addition to performance advantages in spaceflight and aerospace applications that deal with harsh environmental conditions, this added adsorptive capacity combined with conductivity in the fiber velvet mats could be beneficial in electronics manufacturing. Not only does this coated fiber pile eliminate the possibility of electrostatic discharge events, it can also supplant the need for costly vacuum bakeouts. The theoretical increase in surface area for coated velvet fiber mats can be several thousand fold as techniques are refined, and this process innovation could lead to other commercial applications where contamination and charge buildup are of concern.

A final innovation to the adsorber coating is described by the Materials team as a formulation of white molecular adsorber paint (MAC-W), which has shown excellent adhesion to multiple substrates, including but not limited to composites, cellulose-based materials, aluminum, and other metals (GSC-17075-1). The MAC-W coating can also be applied to flexible surfaces and has an improved and more efficient spray process. This improvement opens up the potential for commercial applications such as pharmaceuticals, chemical processing, food production, laser manufacturing, vacuum systems, and air purification systems. Maintaining the advantages of contamination adsorbtion and thermal control, this microscopic nano-textured structure provides a large surface area to mass ratio that maximizes available trapping efficiency. The MAC-W is an excellent example of the kinds of innovations made possible by the Molecular Adsorber Coating platform, and suggests a strong commercial outlook given the flexibility of the technology and ability to adapt the coating to specific performance requirements for niche applications.

4 "NASA paint kills that new car smell, saves satellites too," by Michael Cooney. *Network World*, http://www.networkworld.com/article/2223528/data-center/nasa-paint-kills-that-new-car-smell--saves-satellites-too.html. Accessed July 9, 2014.

Interviews

Graphene

Mahmooda Sultana

ELECTRONICS ENGINEER

Code: 553

Years with NASA: 3.5

Education: PhD, Chemical Engineering, Massachusetts Institute of Technology
BS, Chemical Engineering with minors in Math & Biochemical Engineering, University of Southern California

Q. *How did you get involved with materials science at NASA Goddard?*

I have a multidisciplinary background that includes chemical engineering, electrical engineering, and materials science, which is a good combination for the current work on graphene. I was mostly interested in going to academia until working at Bell Laboratories as a graduate student, which opened the possibility of working at a research and development organization. Growing up I wanted to work at NASA, and that interest returned by the end of graduate school, given some of the exciting missions NASA has been working on.

Q. *What research interests led to working with graphene?*

As I mentioned, I had a strong background suitable for the work on graphene. When I came to NASA Goddard in 2010, no one at the center was doing substantial work on graphene, but there was a lot of excitement because of Dr. [Konstantin] Novoselov's 2010 Nobel Prize in Physics. Everything was still at a very early stage, people around the world were coming up with new applications of graphene everyday. I wanted to explore what graphene had to offer for space applications.

Q. *What are the primary qualities of the material that make it so exciting?*

That is difficult to describe in a single sentence! Graphene has a combination of many extreme properties and it's the combination that makes it so exciting. It is the lightest/thinnest material, but also the strongest material ever measured - 300 times stronger than stainless steel. It is 98% transparent, yet impermeable to even helium or hydrogen. It is radiation hard and is highly stable, making it suitable for space applications. Graphene has very high carrier mobility; exfoliated graphene has 200 times higher carrier mobility than silicon, which, along with high transparency, makes it ideal as a transparent electrode in applications such as touch-screens. Also, it opens the possibility of new types of devices—like science fiction—such as cameras on contact lenses or glasses. The bendability of graphene allows for flexible electronics such as a laptop that can be folded or rolled up and stored, or bendable computers that can fit around your wrist. Instead of a computer on a watch, the whole band could be a screen.

Q. *Primary applications identified by the Materials team at Goddard include microshutter arrays, Schottky photodiodes for UV detectors, cryotank barrier layers, and films for air filters. How would you rank these applications according to commercialization potential and why?*

Graphene is very effective in many of these applications. For next generation microshutter arrays, the device will be much lighter and cheaper. For Gallium Nitride Shottky photodiodes, graphene can increase the quantum efficiency by greater than three times. That means three times as much signal for the same size optics, or the optics can be shrunk by a factor of three, which can significantly reduce the size, and thus the cost, of the overall system. With cryotanks, leaking is a big issue even outside of NASA, and graphene makes an excellent barrier layer. In air filters, graphene could potentially have high impact in really cheap air filters for developing nations that are fighting with air pollution issues. Many of these applications have a niche market though when it comes to commercialization. Applications including "transparent electrode", filters, and chemical sensors have a much broader market and higher commercialization potential than some of the other applications.

One of the most exciting applications of graphene might be in chemical sensors. The EPA is interested in small, portable sensors for chemical plants. It wants to monitor hazardous chemicals and environmental pollutants, and increase the ability to track the origin of pollutants in areas with multiple plants. Cell phone companies like Samsung are interested in incorporating chemical sensors with future smart phones. Homeland security can use it to detect minute concentration of explosives. There are plenty of space applications as well. In planetary science, graphene sensors could be sent as a complementary tool along with traditional mass spectrometers to detect species with mass interference issues. In low budget missions, they might even replace the large and heavy mass spectrometers. Other applications include neutral atom imaging such as atomic oxygen or hydrogen in heliophysics missions, which can help capture the motion of the ionosphere like never before. Finally, there is also potential for graphene chemical sensors in human exploration missions to ensure crew safety by detecting hazardous gas leaks.

Q. *What are graphene's limitations and/or barriers to commercialization?*

The main barrier to commercialization is the difficulty in scaling up the technology, both in terms of size and the amount produced. Today, graphene is mostly made in small sizes and one piece at a time. The larger the graphene, the more difficult it is to manage the homogeneity. The larger the tube, the greater the chance for variation and quality discrepancies. Large graphene is also harder to process and handle, harder to maneuver. Our lab can currently make and process graphene in an area of three-inches by three-inches, but we are working to get to six-inches by six-inches.

In addition, graphene is mostly synthesized and processed in batches. However, two groups have recently demonstrated continuous synthesis. The process will only get better with time. I am optimistic that with processing and manufacturing advances, graphene will be commercially viable and available.

Q. *What has been most rewarding about working with graphene at NASA Goddard?*

It has been extremely rewarding to work on a project with such high potential and to see the ideas in my head and those of my colleagues come to life before our eyes. The Internal Research and Development (IRAD) program has been very supportive of the graphene initiative, which has also been encouraging.

Q. *Can graphene live up to its hype?*

People often ask me this question due to the past example of carbon nanotubes, which were thought to be a major breakthrough technology but have not materialized as such. Why is graphene different? Carbon nanotubes were discovered in the early 1990's, but more than 20 years later there has not been any major commercial application. The case of graphene is much different. Large-area graphene was first demonstrated in 2009, and within just five years, great progress has already been made in developing infrastructure to process the new material, improving those processes and demonstrating some potential commercial products. For example, Samsung has developed a graphene-based touchscreen and is just waiting for commercial introduction. The cost of graphene is in the process development. Once that is taken care of, the material is pretty cheap to make. It's just a matter of time before we see graphene in commercial applications.

NASA Goddard's Lotus Coating Development Team from left to right: Victoria Stotzer, Alexson Kirksey, Kenneth O'Connor, Stephen Lebair and Mark Hasegawa. Not pictured are Sharon Straka and Nithin Abraham.

—PHOTO BY NASA

Innovative Coatings

Q. How did NASA Goddard get involved with coatings technology?

NASA Goddard has had a very long and successful history of space flight coatings going back to the late 1960's and early 1970's. Goddard has developed a number of coatings for thermal control and has the capacity to manufacture and apply advanced coatings in-house. In recent years, our group has started looking at other programmatic needs beyond thermal coatings to offer solutions based on our experience and expertise. For instance, the Lotus WC2 Coating has only been in development for a couple of years, but has already successfully demonstrated unique properties for dust mitigation and anti-contamination in harsh space environments. In addition, the group has developed a sprayable family of molecular adsorber paints that adsorb outgassed molecules both in vacuum and air. This coating can be used to control molecular contamination and prevent degradation of instrument performance, thermal control properties, optical surfaces, laser systems, detectors, cryogenic instruments, and high powered electronics.

Q. How does the Coatings Group foster new innovations at NASA Goddard?

Although the primary responsibility of our particular group is applying and flight qualifying thermal control coatings, developing new cutting edge coatings to solve flight hardware issues has also become a priority. New innovative coatings are being developed to address concerns in thermal engineering and contamination engineering, as well as, other subsystems to prevent degradation or, in some cases, improve performance. Our group is very attentive to the program needs at NASA Goddard and across the agency and is constantly working to develop coatings to meet those needs or adapt our technologies to new applications. We also work directly with customers to engineer the coatings to specific performance requirements.

Q. What are the primary qualities of the coatings that make them so exciting?

The Molecular Adsorber Coating is made from a highly porous zeolite base, which can adsorb molecular contaminants, particularly hydrocarbons, as well as gases. The coating can also be engineered to provide variations for specific applications, but its main advantage is its ability to mitigate contamination. The flight qualified coating is white, but a black version of the molecular adsorber coating is being tested for use inside instruments to concurrently address stray light issues or provide thermal control.

The Lotus Coating does not use the lotus plant itself; it is designed to simulate hydrophobic and self-cleaning properties using a leaf-like nano-texture. In the naturally occurring plant structure, water beads up and does not stick on the surface and dirt readily comes off the leaves. This is a desirable property in dusty environments like the moon or Mars. The group has been successful in creating that same effect in a lightweight transparent or translucent coating, depending on the formulation. The Lotus Coating was initially focused on manned spacecraft missions to the moon and reducing harm to the crew, but it also helped meet the broader goal of reducing particulate contamination on all spacecraft, as well as liquid adsorption.

Q. What has been most challenging in development of these coatings?

When developing new coatings, one of the greatest challenges is optimization. We have to trade one property for another, and try to maximize the overall performance without compromising specific advantages. For example, the Lotus Coating has been manufactured to be optimally durable, highly hydrophobic, and transparent. If one property is more important than other properties of the coating, the coating can be adjusted to optimize the most important properties. Another challenge in developing coatings for space flight applications is that the coating must survive the harsh space environments. These harsh space environments often prevent NASA from using outside (commercial) products, which were developed for terrestrial applications.

Q. *Are there any barriers to commercialization?*

We had initially been working with an outside company, but it was difficult to manage quality control and durability, and the coating could not be applied to large surfaces, so we completely abandoned that effort and developed our own coating based on a completely different composition and application technique. This allows us to customize the coating to specific applications and apply the coating to much larger surfaces. Going in a different direction also allowed us to focus more intently on the main barriers to commercialization. For the Lotus Coating, that meant achieving full-scale development with the required durability, clarity, and nano-texture. For the Adsorber Coating, we needed to focus on capacity, adhesion, and color. By altering the color, we can cater the coating to specific applications. We currently have two molecular adsorber coatings, the MAC-W white paint and the MAC-B black paint. Since we are also a manufacturing and coating applications facility, it is important for us to work closely with the customers to understand their unique requirements and be able to scale up directly in the lab.

Q. *What is next for the Coatings Group at NASA Goddard?*

It is safe to say that we have a number of customers right now and that we are tailoring the coatings to their needs. We are working closely with the Innovative Technology Partnership Office to commercialize some of the coatings. We are also innovating on the existing Adsorber Coating, transforming the MAC-W and MAC-B to be electrically conductive or dissipative. With respect to the Lotus Coating, we are developing a coating that exhibits no degradation of the dust mitigation and hydrophobic properties as you wear through the coating down to the substrate. Furthermore, in addition to developing improved thermal coatings, we are working on a nano-coating that will generate power similar to a solar cell. This coating is based on quantum dot technology and is intended for applications such as CubeSat and spacecraft with solar concentrators. Within our team, we highly encourage team members to generate publications to show progress and generate interest in the coatings. These papers help NASA Goddard gain recognition, foster partnerships, and let potential customers know we are a manufacturing and applications facility as well.

NASA GODDARD'S LOTUS COATING DEVELOPMENT TEAM

Mark Hasegawa
Thermal Coatings Application and Development Group Lead
CODE: 546
YEARS WITH NASA: 11
EDUCATION: BS, Chemical Engineering, University of California at Berkeley
MS, Environmental Engineering, Tufts University

Kenneth O'Connor
Thermal Coatings Research and Development Engineer
CODE: 546
YEARS WITH NASA: 3
EDUCATION: BS, Chemical Engineering, Clemson University

Sharon Straka
Mission Manager, Earth Sciences Division
CODE: 420
YEARS WITH NASA: 26
EDUCATION: BS, Chemical Engineering, University of Pittsburgh

Nithin Abraham
Coatings Development Engineer
CODE: 546
YEARS WITH NASA: 4
EDUCATION: BS, MS, Chemical Engineering, Manhattan College, NY

Victoria Stotzer
NASA Pathways Intern
CODE: 546
YEARS WITH NASA: 2
EDUCATION: BS, Chemistry, George Mason University; 1st Year Graduate Student, Chemistry, University of California at Davis

Alexson Kirksey
Intern
CODE: 504
YEARS WITH NASA: 5
EDUCATION: Senior, Physical Sciences, University of Maryland

Stephen Lebair
NASA OSSI Summer Intern
CODE: 546
YEARS WITH NASA: 1
EDUCATION: Sophomore, Materials Engineering, University of Maryland

[SBIR/STTR *Success Story*

SBIR/STTR Success Story

In each issue of Tech Transfer News we feature a SBIR/STTR success story to highlight the important work of collaboration between NASA Goddard and industry, along with the vision required to move technology from the lab to the marketplace. The Small Business Innovation Research (SBIR) program is designed to facilitate cutting-edge R&D, and NASA Goddard is pleased to support technologies with the potential to make an impact in mission-based and commercial applications.

The Affordable Pre-Finishing of Silicon Carbide for Optical Applications

In collaboration with Creare Inc. (Dr. Jay Rozzi, Principal Investigator), NASA Goddard helped develop an affordable pre-finishing machining process for super-hard ceramics, to be used primarily in optical applications. Future observational and exploratory missions will depend on lightweight, large aperture telescopes; and optical mirror technologies need to be both cost-effective and scalable to meet the demands of long duration space flight. Processes achieved in the lab need to be demonstrated for use in NASA mission applications, along with alternative applications that can help refine the technology for commercial viability. The work carried out in this SBIR Phase II project was intended to address these issues.

Chemical vapor deposition (CVD) coated silicon carbide (SiC) has shown promise as a highly stable material for lightweight optical mirrors; however, the challenge of affordable manufacturing techniques to pre-finish SiC has yet to be overcome. According to a Project Summary provided by Peter Blake, Technical Officer at NASA Goddard Space Flight Center, "Our approach for this project was to develop a hybrid machining process for Si or SiC. This process is based on two unique and deterministic processing steps that both utilize a single-point diamond turning (SPDT) machine. In the first step, a high material removal rate (MRR) process is used to machine the part within several microns (<5 μm) of the final geometry. In the second step, a low MRR process is used to machine the part to a pre-finish quality, preparing the surface for final optical finishing. This step is based on a ductile regime machining (DRM) process that we developed during our Phase I project." [1]

While Mr. Blake couldn't speak to the commercial success of this machining process following completion of the Phase II project, Creare Inc. has information pertaining to "Ultraprecision Machining" on their company website, claiming: "Our approach combines a high-speed process, known as spin-turning, with a low-speed process, known as ductile regime machining, to produce prefinished silicon carbide mirrors that are free of SSD and that cost 80% less than grinding. This technology was developed using SBIR funding from the Navy and NASA." [2]

Finding an optimized and affordable pre-finishing machining technique for silicon carbide would allow faster adoption of next-generation optical mirrors for use in lightweight telescopes. These advanced telescopes and their corresponding optical technologies are crucial for the future of space exploration. Outside of NASA Goddard and space flight applications, cost-effective manufacturing of super-hard materials like SiC will enable commercial acceptance of this advanced technology. Silicon carbide has significant material advantages over other options, but cost has been a prohibitive barrier to commercial entry. Applications in aviation, automotive, cutting tools, and artificial joints all stand to benefit from affordable advances in materials science.

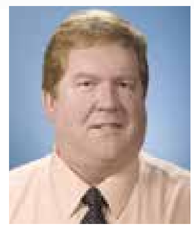
1 "The Affordable Pre-Finishing of Silicon Carbide for Optical Applications," Project Summary, Contract No. NNX09CA66C.

2 Creare Inc., "Machining Technology," http://www.creare.com/services/manufacturing/machining.html. Accessed on September 11, 2014.

PROTECTING MATERIALS *Intellectual Property*

Patenting Perspectives

Materials science has long been established as an active arena for Intellectual Property (IP). As Bryan Geurts (Chief Patent Counsel for NASA Goddard's Office of Patent Counsel) explains, when a technology area is considered a crowded art, there are particular IP challenges that involve the scope and structure of patent claims. He also offers some insight into the IP dynamic at NASA Goddard, and how the Office of Patent Counsel encourages close collaboration between all of the interested parties in a particular technology area to ensure a cohesive IP strategy. This integration of R&D efforts with IP perspectives helps protect NASA Goddard technologies, and also contributes to the recognition and status of the scientists, engineers, and project managers who define Goddard's culture of innovation. With such targeted coordination, tech transfer and commercialization are not merely by-products of R&D—they become a valuable part of the process.



Bryan Geurts

CHIEF PATENT COUNSEL

Code: 140.1

Years with NASA: 12

Education: Education: BS, Civil Engineering, BA German, University of Utah JD, Brigham Young University

Q. Has there been NASA Goddard IP generated through Materials-related research?

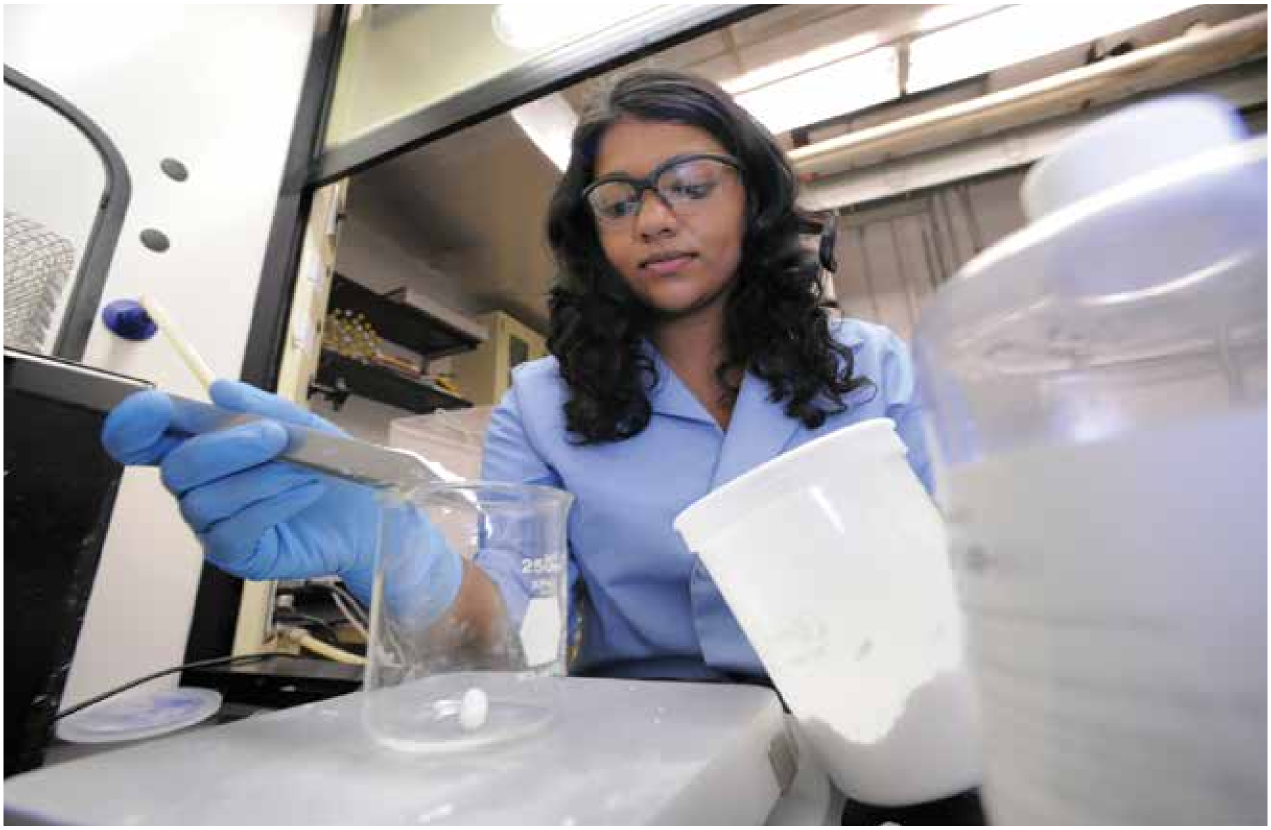
Oh yes, on all three of the featured technologies and others. Materials research is very active at Goddard and other centers. We do it and protect them as well. The intent is to have patent-pending status. My overall observation is that we're very active in that area.

Q. Are there any IP challenges specific to Materials technology?

There are always unique challenges to each type of technology group. For example, in electronics there are a certain set of challenges, same as materials or any other set. One of them is the way we claim the material—the claim structure can vary. Depending on the type of material there are certain claim structures that make sense over others, so we work to match the technology with the best claim. This is especially true when dealing with chemical materials.

Q. What are the IP strategies for dealing with innovations to preexisting technologies such as graphene or the Lotus Coating?

In general, IP has "hot" technology and "cold" technology. Graphene right now is hot; there are a lot of patents and it is a crowded art. When this is the case, the scope of the claim becomes narrower. We are not going to be recognized as leaders, but there is no *one* clear leader, and people are jockeying for position through IP. The same holds for the Lotus Coating group: the more people doing work in the field, the narrower the scope of protection, and people try to snatch up whatever they can get.



▶ *Nithin Abraham works on an anti-contaminate coating that could have commercial applications in aerospace, automotive, pharmaceutical, and a host of other industries..*

—PHOTO BY NASA

Q. ***How does your office work with NASA Goddard personnel to help facilitate tech transfer opportunities?***

As I like to characterize it, there are three distinct thinking groups at Goddard: the first is the scientists, the second is the engineers, and the third is project managers. Engineers tend to be very methodical and look to maximize efficiency. Project managers are focused on keeping a project on task and schedule, and want to have it done by a certain date. Scientists are curious about everything; if you give them funding they will try to keep the project going forever to learn as much as they can.

Scientists also want to share with everybody in the spirit of pursuing knowledge and discovery. If they don't talk to the IP office, however, it can be difficult to protect new innovations. Proprietary rights are not necessarily priorities, but some have joined the bandwagon and understand IP is there to help. We can enhance the status of the scientist, group, and research, while also providing recognition in the community. Patents help recognize leaders and provide more funding sources for paths of inquiry. We want to be seen as friends to R&D rather than a roadblock.

Q. ***Is there a Materials area you think is particularly exciting from an IP perspective?***

Wow, that's kind of a loaded question! A technology area is exciting from an IP perspective if it's a crowded art, because the challenges posed in finding the right structure and scope of claims. It's a huge success story for our office if we can have something that is drawn around a good scope, but large enough to bring inventors real kudos in the community. If we have carved out a large enough scope to bring recognition, we feel like we have done our jobs well and improved the culture of innovation at Goddard.

Materials In the News

NASA Goddard "super-black" coating makes headlines

An article posted on *ExtremeTech.com* in July, 2013 ("NASA's super-black coating could revolutionize space telescopes, stealth vehicles") features a new "super-black" coating, fashioned out of carbon nanotubes, and designed to absorb light. According to the article, the super-black coating "absorbs more than 99% of ultraviolet, visible, infrared, and far-infrared light, making it the perfect lining for telescopes and other incredibly sensitive instruments that are tasked with picking out a handful of photons from an entire universe of light pollution." The multi-walled carbon nanotube (MWNT) coating is also being evaluated for military applications, since MWNTs absorb microwaves as well, making it an ideal candidate for stealth vehicles that need to evade radar detection.

More information on the super-black coating can be found at http://www.extremetech.com/extreme/161657-nasas-super-black-coating-could-revolutionize-space-telescopes-stealth-vehicles

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Repsol-funded graphene company recognizes NASA Goddard R&D

Graphenea, a European technology company that produces graphene, highlighted NASA Goddard's work on graphene in a blog post from December, 2012. The post, which describes NASA Goddard's progress in developing chemical sensors based on graphene, also credits the efforts of Mahmooda Sultana (see her interview in this issue) and Fred Herrero.

Graphenea was established in 2010 with support from Repsol, one of the world's largest oil and gas companies. It's investment in graphene signals the dramatic commercial potential for this advanced materials technology.

To read the Graphenea blog post, visit the company's website: http://www.graphenea.com/blogs/graphene-news/7039406-nasa-is-developping-graphene-based-sensors

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From spacecraft to new cars, NASA Goddard coatings are newsworthy

The website *Network World* ran a story in November, 2012 on the molecular adsorber coating featured in this issue. Mentioned in the article is Mark Hasegawa (interviewed in this issue as part of the Lotus Coating Development Team), who explained the advantages of the technology as an easy and low-cost solution for dangerous outgassing. The article also notes interest from industry players, including Northrop Grumman; the European Space Agency; the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder; and Spica Technologies.

To read the article in its entirety: http://www.networkworld.com/article/2223528/data-center/nasa-paint-kills-that-new-car-smell--saves-satellites-too.html

Dr. William Forstchen speaks during the 21st Annual New Technology Reporting Program.

—PHOTO BY NASA

21st Annual New Technology Reporting Program

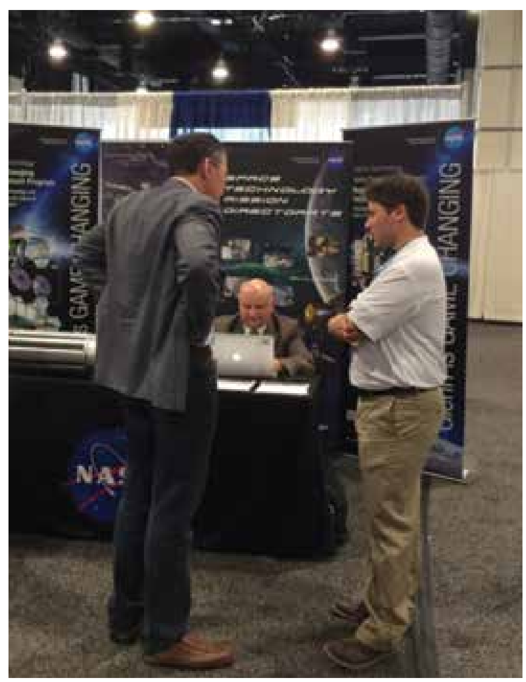
(MARCH 27, 2014, BELTSVILLE, MD)

The Innovative Technology Partnerships Office (ITPO) hosted its 21st Annual New Technology Reporting Program on March 27, 2014 at the National Agricultural Library in Beltsville, MD. This annual event gathers together Goddard innovators, contractors and personnel to recognize the importance of technology transfer, and celebrate innovator participation in Goddard's new technology reporting program, as well as innovators who have had their technologies patented.

Key highlights included the presentation of the prestigious James Kerley Award to Geoffrey Bland and Ted Miles in recognition of their technical leadership, technology commercial achievement and outstanding support for technology transfer and new technology reporting related to Aeropods; Senior Vice President of Engineering at Cessna, James Thacker delivered the programs keynote presentation sighting the parallels between fostering an appreciation for commercialization at Cessna and at NASA Goddard; Author and Professor Dr. William Forstchen spoke of his experience of collaborating with Goddard subject matter experts while writing his book *Pillar to the Sky*, and the presentation of the ITPO's NTR Award, presented to Code 580 for their outstanding efforts in new technology reporting during the 2013 fiscal year.

2014 ARPA-E Energy Innovation Summit

(FEBRUARY 24-26, NATIONAL HARBOR, MD)



NASA staff members hosted a booth at the 2014 ARPA-E Energy Innovation Summit.

—PHOTO BY NASA

NASA participated in the 2014 ARPA-E Energy Innovation Summit at the Gaylord National Hotel and Convention Center in National Harbor, MD. The Innovative Technology Partnerships Office (ITPO) represented NASA Goddard along with representatives from NASA's Glenn Research Center. The ARPA-E Energy Innovation Summit is an annual event held to bring together thought leaders from academia, business, and government to discuss cutting-edge energy issues and facilitate relationships to help move technologies into the marketplace. There were close to 3,000 summit attendees who provided a steady stream of showcase attendees. NASA received several inquiries in specific areas such as electronics, solar energy, and batteries.

2014 New Year's Poster Party

(JANUARY 29, 2014, GREENBELT, MD)

An attendee visits the Innovative Technology Partnerships Office table during the 2014 New Year's Poster party.

—PHOTO BY NASA

NASA Goddard's Innovative Technology Partnerships Office (ITPO) took part in the 7th Annual Sciences and Exploration Directorate New Year's Poster Party on January 29th in the building 28 atrium. This annual event offers participants a great opportunity to display their posters from 2013 conferences or to make and display new posters showcasing their work. The ITPO met and talked with attendees about its role in managing new technology reports, developing partnerships and licensing opportunities.

Association of University Technology Managers (AUTM) Annual Meeting

(FEBRUARY 19-22, 2014, SAN FRANCISCO, CA)

NASA Goddard's Innovative Technology Partnerships Office (ITPO) staff attended the annual meeting of the Association of University Technology Managers (AUTM) in San Francisco. This year's meeting saw more than 1,800 technology transfer professionals from around the world and featured networking, professional development, and sessions with national and international experts on trends in technology transfer. AUTM's members represent intellectual property managers from more than 300 universities, research institutions, teaching hospitals, businesses, and government agencies.

Innovative Initiatives with Dr. Ron Adner

(MARCH 27, 2014, GREENBELT, MD)

To facilitate a conversation about managing innovations (both technology and business management practices), Goddard management, scientists, and engineers were invited to participate in the ITPO's Innovative Initiatives Workshop Spring 2014 on March 27, 2014. Dr. Ron Adner, Professor of Strategy at Tuck School of Business, Dartmouth University, and author of the bestseller The Wide Lens: What Successful Innovators See that Others Miss, joined Goddard leaders to lead a discussion on how important the interdependent interests of collaborating individual innovators and managers are to the collective interest—"big picture"—of Goddard and vice versa.

Innovative Technology Partnerships Office Chief, Nona Cheeks, along with Cessna Senior Vice President of Engineering, James Thacker and Dr. Ron Adner, talk with Goddard Management during the spring 2014 Innovative Initiatives Workshop.

—PHOTO BY NASA

Oakland Terrace Elementary School Visits Goddard

(FEBRUARY 12, 2014, GREENBELT, MD)

NASA staff members hosted a booth at the 2014 ARPA-E Energy Innovation Summit.

—PHOTO BY NASA

The Innovative Technology Partnerships Office (ITPO) participated in Goddard's hosting of students from Silver Spring, Maryland's Oakland Terrace Elementary School. The ITPO was on hand to talk with students about NASA spinoff technologies and to demonstrate NASA's Massively Multiplayer Online (MMO) game, Starlite – Astronaut Rescue, which challenges players with math and engineering questions that must be solved in order to advance further in the game. The students were also given a tour of the James Webb Space Telescope clean room and were treated to a demonstration of infrared imaging and a model of Goddard's centrifuge. .

Society of Manufacturing Engineers Technology Interchange

(FEBRUARY 19, 2014, DEARBORN, MI)

The Innovative Technology Partnerships Office (ITPO) participated in the Society of Manufacturing Engineer's (SME) Technology Interchange, featuring NASA Technologies. The event brought together stakeholders from industry, academia, and government to engage in strategy development, partnership building and implementation of ways to foster technology collaboration and innovation. Goddard Space Flight Center featured technology developed by Betsy Pugel, PhD, entitled "Portable Low Cost Nondestructive Materials Testing via UV Spectroscopy". The technology garnered interest that has led to interest and application exploration by two companies following the event.

Technology Innovation and Innovator Training

(MARCH 11, 2014, GREENBELT, MD)

The Innovative Technology Partnerships Office (ITPO) offered its Technology Innovation and Innovator Training to civil servants and contractors, showing how innovative ideas can be translated into commercial success. The ITPO provided attendees with information on technology transfer, how partnerships are formed with industry and NASA inventions are brought to market.

Tor-Forge Pillar to the Sky Book Launch

(FEBRUARY 19, 2014, GRENNBELT, MD)

Local high school and university students were invited to attend a public speaking engagement with Goddard scientist Dr. John Panek and New York Times bestselling author of *Pillar to the Sky*, William Forstchen, on February 19, 2014 at Goddard's Visitor Center. The event celebrated the partnership between Goddard's Innovative Technology Partnerships Office (ITPO) and Tor Books in releasing the new book, which is the first title in a new series of "NASA-Inspired Works of Fiction" that are intended to not only educate, but also encourage young adults to examine the rewarding careers that science and technology have to offer. With the enormous popularity of science fiction—countless people who work in the fields of science and technology credit science fiction as a significant inspiration for their career choice—the ultimate goal of the series is to raise awareness and inspire the study of the STEM subjects (science, technology, engineering and mathematics), while educating the general public on the significant role NASA plays in everyday lives.

Technology Disclosures

Disclosures

- **A FAST-RESPONSE MULTI-HOLE PROBE FOR HARSH HUMID CONDITIONS**

  Demetri Telionis

- **THE MAGNETOSHPERIC MULTISCALE (MMS) OPTICAL BENCH ASSEMBLY (OBA)**

  Rommel Zara, Richard D'Antonio, Nicholas Teti

- **A SUBMERSIBLE INSTRUMENT TO MEASURE VOLUME SCATTERING FUNCTION OF WATER FROM 0.1 TO 150 DEGREES**

  Yogesh Agrawal

- **CLIMATE DATA SERVICES APPLICATION PROGRAMING INTERFACE (CDS API) CLIENT DISTRIBUTION PACKAGE**

  Glenn Tamkin, John Schnase, Daniel Duffy

- **VERILOG-A COMPACT MODELS FOR CRYOGENIC TEMPERATURE OPERATION OF CMOS DEVICES AND INTEGRATED CIRCUITS**

  Siddharth Potbhare, Neil Goldsman, Akin Akturk

- **OCEAN COLOR AT NIGHT**

  Stanford Hooker, Charles Booth, Randall Lind, John Morrow

- **MEMETIC COMMUNICATIONS AND LEARNING FOR NETWORKED SYSTEMS**

  Christopher Rouff, Mohammad Akhavannik, Walt Truszkowski

- **HIGH FIDELITY, RADIATION TOLERANT ANALOG-TO-DIGITAL CONVERTER**

  Umran Inan, Ivan Linscott, Charles Wang

- **AUGMENTED TELEPORTATION AND TELEKINETIC SYSTEM**

  Eleanya Onuma

- **A TISSUE PROPAGATION MODEL FOR VALIDATING CLOSE-PROXIMITY BIOMEDICAL RADIOMETER MEASUREMENTS**

  Quenton Bonds

- **XML TELEMETRIC AND COMMAND EXCHANGE (XTCE) ADVANCED MULTI-MISSION OPERATIONS SYSTEM (AMMOS) TOOL SUITE 1.0**

  James Rice

- **CLIMATE DATA SERVICES APPLICATION PROGRAMING INTERFACE (CDS API) REFERENCE MODEL, LIBRARY, AND COMMAND INTERPRETER**

  Glenn Tamkin, John Schnase, Daniel Duffy

- **RESONANCE-ACTUATION OF MICROSHUTTER ARRAYS (2013)**

  Yiting Wen, Mary Li, Liqin Wang, S. Harvey Moseley, Alexander Kutyrev

- **METHOD FOR RADIOMETRIC CALIBRATION OF SIGNAL-OF-OPPORTUNITY BISTATIC RADARS AND REFLECTOMETERS USING INTERNAL ELECTRONIC SOURCES**

  Jeffrey Piepmeier

- **"WORLDVIEW" SATELLITE IMAGERY BROWSING AND DOWNLOADING TOOL**

  Ryan Boller, John McGann, Kevin Murphy, Shriram Ilavajhala, Jeffrey Schmaltz, Elizabeth Timmons, Taylor Gunnoe, Matthew Cechini, Tilak Joshi

- **FLIGHT LOSSLESS DATA COMPRESSION ELECTRONICS**

  Lowell Miles

- **OPTICAL ENHANCED INFRARED DETECTOR**

  Jarrod Vaillancourt

- **HIGH PERFORMANCE SCIENCE CLOUD: CONCEPT, DESIGN, ARCHITECTURE, AND OPERATION**

  Phillip Webster, Mark McInerney, John Schnase, Daniel Duffy

▶ **STIFFNESS-TAILORED COMPOSITE DRIVESHAFT**

Daniel Hatfield, Jeremy Novara, Neil Boertlein

▶ **A NOVEL FLIGHT TERMINATION DEVICE FOR UNMANNED AIRCRAFT**

Neil Boertlein, Daniel Hatfield, Jeremy Novara

▶ **GODDARD X-RAY NAVIGATION GROUND TESTBED**

Monther Hasouneh, Jason Mitchell, Zaven Arzoumanian, Keith Gendreau, Harry Stello, Luke Winternitz

▶ **MINIATURIZED AIRBORNE IMAGING CENTRAL SERVER SYSTEM**

Xiuhong Sun

▶ **C12A7 ELECTRIDE HOLLOW CATHODE**

Lauren Rand, John Williams

▶ **WING-FUSELAGE INTERFACE GEOMETRY FOR MINIMUM INTERFERENCE DRAG**

Daniel Hatfield, Neil Boertlein

▶ **OTIS/TPXO**

Lana Erofeeva, Gary Egbert

▶ **DEKA-CAPACITIVE DISCHARGE IGNITION (DEKACDI)**

Michael Smolinski, Gregory Waters, Scott Hesh

▶ **A NEAR-EARTH-ASTEROID, SPACE-BASED CAMERA SUITE**

Peter Smith, Bashar Rizk, Charles Fellows, Christian Drouet D'aubigny

▶ **CLIMATE DATA SERVICES APPLICATION PROGRAMING INTERFACE (CDS API) MERRA ANALYTIC SERVICES (MERRA/AS)**

John Schnase, Daniel Duffy, Glenn Tamkin, Mark McInerney, Denis Nadeau, John Thompson, Scott Sinno

▶ **TECHNIQUE TO MAINTAIN HIGH THROUGHPUT AS A NOVEL ELECTRO-OPTIC LASER DEFLECTOR IS SCANNED**

Scott Davis

▶ **SPACE QUALIFIED, RADIATION HARDENED, DENSE MONOLITHIC FLASH MEMORY**

Bert Vermeire

▶ **ENGINEERING STATUS REPORTING TOOL (ESRT)**

Malinda Hammond

▶ **SITUATIONAL AWARENESS SYSTEM (SAS) REL 2.0**

James Reis, Anthony Cruz

▶ **SYNCHRONIZING CLUTCH FOR PROPELLER-DRIVEN AIRCRAFT**

Neil Boertlein

▶ **AFB DOUBLE-CLAD LARGE MODE AREA SINGLE-MODE CRYSTALLINE FIBER-WAVEGUIDES FOR MOPA AND LASER APPLICATIONS**

Xiaodong Mu

▶ **OPTICAL CORRELATION RECEIVER**

Michael Krainak

▶ **A TWO-DIMENSIONAL PHONONIC METAMATERIAL STRUCTURE FOR THERMAL CONDUCTANCE DEFINITION**

David Chuss, Kevin Denis, Samuel Moseley, Karwan Rostem, Edward Wollack

▶ **PI-SAT: A LOW COST DISTRIBUTED SPACECRAFT MISSION TEST BED**

Alan Cudmore

▶ **MMS GOLD PLATED RINGS A PASSIVE HEAT SOURCE**

Rommel Zara, Nicholas Teti

▶ **SOFTWARE FOR AUTOMATED GENERATION OF REDUCED ORDER MODELS FOR SPACECRAFT THERMAL ANALYSIS**

Yi Wang, Jing Qian, Hongjun Song, Kapil Pant

▶ **DETERMINATION OF THE EFFECT OF POSTCURE AND ASSOCIATED DESIGN ALLOWABLES FOR M55J/RS-3C POLYCYANATE COMPOSITE**

Frank Horey, Ashley Kashiwabara, Brian Hill

▶ **CLIMATE DATA SERVICES APPLICATION PROGRAMING INTERFACE (CDS API) PERSISTENCE SERVICES (PS)**

Daniel Duffy, Glenn Tamkin, Mark McInerney, Denis Nadeau, John Thompson, John Schnase, Scott Sinno

▶ **NASA INDEPENDENT VERIFICATION AND VALIDATION PROGRAM (IVVP) RISKMANAGER TOOL**

Bryan Walker, Jeremy Williams, Nathaniel Jones, Christopher Williams

▶ **AFB COMPOSITE SINGLE CRYSTAL SILICON MIRROR SUBSTRATES**

Xiaodong Mu

▶ **OPTIMIZATION OF HIGH TEMPERATURE SUPERCONDUCTING (HTS) SOLENOID MAGNETS BY TUNING THE HTS TO ACCOUNT FOR THE SUPPRESSION OF THE CRITICAL CURRENT (IC) BY THE RADIAL COMPONENT OF THE MAGNETIC FIELD GENERATED**

Christopher Rey, Trever Carnes

▶ **CUBESAT COMPATIBLE HIGH RESOLUTION THERMAL INFRARED IMAGER**

Murzban Jhabvala, Donald Jennings, Compton Tucker

- **GSFC DYNAMIC ANALYSIS SOFTWARE**

  Daniel Worth, Timothy Schwartz, Brian Ross, Christopher McLeod

- **NTR GAME FOR IPAD (NAME SUBJECT TO CHANGE)**

  Adil Anis, Eunice Corbin

- **LIQUID CORE TRANSFORMER (LCT)**

  Eleanya Onuma

- **SWIRL BLADELESS FAN**

  Eleanya Onuma

- **ADVANCED TECHNOLOGY CLOUD PARTICLE PROBE FOR UAS**

  Paul Lawson

Patent Applications Filed

- **OPTICAL NULL LENS VERIFICATION USING IMAGE-BASED WAVEFRONT SENSING**

  Peter Hill, Patrick Thompson, David Aronstein, Matthew Bolcar, Jeffrey Smith

- **NITINOL-ACTUATED NORMALLY OPEN PERMANENT ISOLATION VALVE**

  Daniel Ramspacher, Caitlin Bacha

- **RESIN IMPREGNATED CARBON ABLATOR (RICA): A NEW ABLATIVE MATERIAL FOR HYPERBOLIC ENTRY SPEEDS**

  Jaime Esper, Michael Lengowski

Patents Issued

- **NOVEL SUPERCONDUCTING TRANSITION EDGE SENSOR DESIGN**

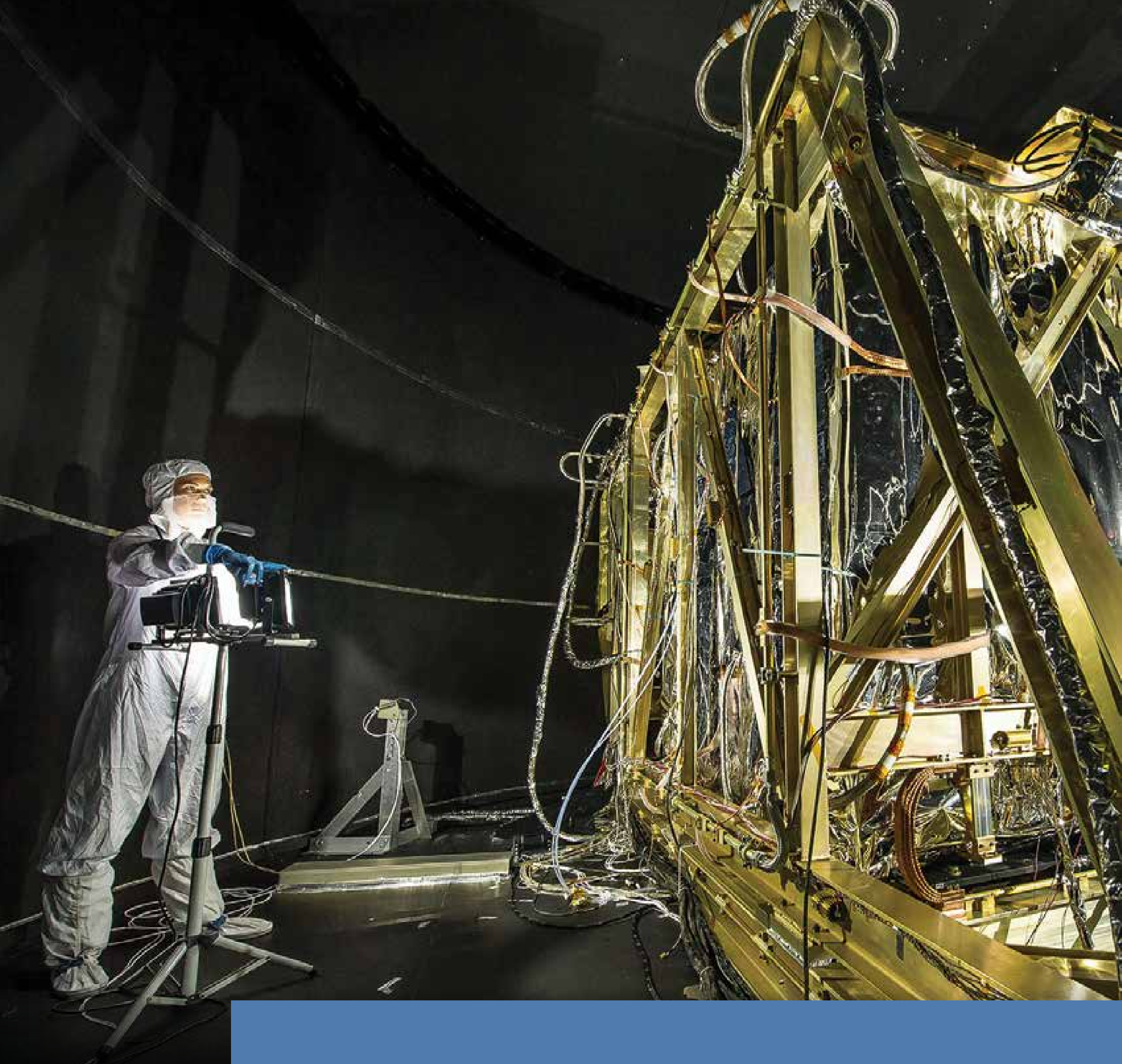
  John Sadleir

Materials Science

Agreements

[SPACE ACT *Agreement*

COMPANY	AGREEMENT TYPE	PARTNERSHIP ABSTRACT
Google, Inc.	*Interagency Agreement*	*Funding for studies determining the effects of space weather on data center error rates and stability.*
littleBits Electronics, Incorporated	*Space Act Agreement*	*NASA's Aura mission and littleBits wish to collaborate in the development of a unique educational product that engages young children in NASA technology through the use of an electronic children's toy. Specifically, the Parties will jointly prototype and develop an innovative set of electronic components with supporting hands-on activities focused on the electromagnetic spectrum at wavelengths used in Earth remote sensing science (UV, Visible, IR and Microwave).*



▶ *A spotlight shines on the James Webb Telescope, which will take advantage of advanced materials engineered and developed at NASA Goddard.* **—PHOTO BY NASA**

NASA Goddard Tech Transfer News [**http://itpo.gsfc.nasa.gov**]

NASA Goddard *Tech Transfer News* is the quarterly magazine of the Innovative Technology Partnerships Office (Code 504) at NASA's Goddard Space Flight Center. Also available online at: http://itpo.gsfc.nasa.gov.
Send suggestions to Robert.S.Leonardi@nasa.gov.

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