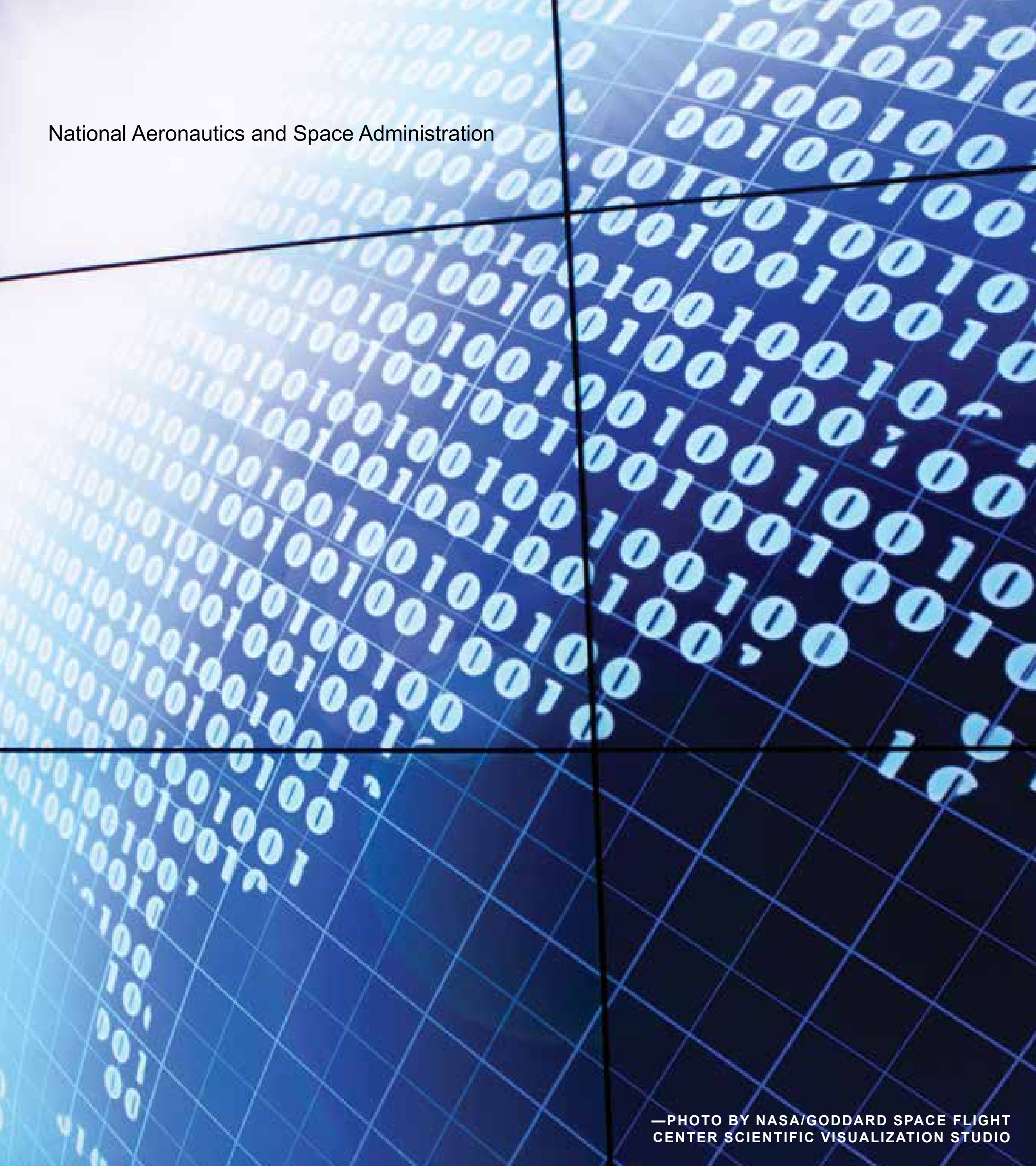
National Aeronautics and Space Administration



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GSFC NEWS

tech transfer

Big Data

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Big Data

Nona Cheeks

[FROM THE *Chief*

From the Chief

It's no secret: Big Data is big business. Large, multi-national corporations like IBM and Oracle have long understood the economic potential intrinsic to the Information Age, helping companies maximize efficiency and productivity with data storage, management, and analytics. More recently, internet giants such as Amazon, Google, and Facebook have entered the Big Data market at various stages and offering a host of both products and services, ranging from targeted advertising to cloud computing, and all promising in some way to deliver the future of artificial intelligence. We are at a critical point in the history of design and technology, where the unbounded enthusiasm for progress and the sincere optimism for what is possible must reconcile with the realities of climate change and the often haunting portrayals of data-driven societies in science fiction. Great power and great responsibility walk hand-in-hand through the world of Big Data.

While science, technology, and policy try to work together on a global scale to help all people flourish, here at NASA Goddard, our Earth Sciences R&D continues to make real impacts around the world. From the breathtaking visualizations produced by the Scientific Visualization Studio, to the disaster management and relief support provided by our Earth Observing System Clearing House (ECHO), we are helping to change the way we understand our own planet. Big Data certainly has tremendous commercial value, but it can also help save lives and empower communities by increasing access to information and tools that serve humanitarian needs. As Dr. Dalia Kirschbaum aptly states in her interview with *Tech Transfer News*, "People tend to know NASA for what we do in space, but don't know about what we can do on Earth and at a local scale to help society."

As you will read in our interview with Bryan Geurts (Chief Patent Counsel), one of the things that makes Big Data an exciting and challenging arena from a tech transfer perspective is the fact that most of NASA Goddard's data is available for free. As much as we understand the sincere scientific value of our data, we also know that there are substantial commercial opportunities to use our services and products as a revenue stream. The same raw data that leads to natural disaster management, can also be used—when refined with the right filter—by natural resource firms, insurance companies, or analytics providers. Many of the technologies featured in this issue are related to ongoing efforts to refine raw data and develop more sophisticated modeling capabilities. In addition to this important work—how we use, process, and deliver the enormous amount of data collected at NASA Goddard—there are also numerous technologies pertaining to the platforms of data management and storage. It should come as no surprise that Goddard is at the forefront of cloud computing, and our scientists, engineers, and project managers are hard at work to build Big Data architecture that pushes the transformative limits of the cloud even further.

Whether coding new algorithms or producing imaginative videos, NASA Goddard Space Flight Center is quick to embrace the incredible talent and dedication that drives our culture of innovation. Many of the projects and technologies described in these pages are the product of multi-year programs, where continuity and collaboration are essential. They also demonstrate unique combinations of backgrounds and research interests, and highlight the fact that science and creativity are not strange bedfellows in the work we do. With so much emphasis being placed on the power of Big Data to influence the course of history and define our future, it is only fitting that we remember a time-honored tradition between colleagues at NASA Goddard: let's work together to leave this planet a better place for all.

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

[BIG DATA *at NASA Goddard*

Big Data

The term "Big Data" doesn't sound like a very precise designation for an industry with enormous market growth and dramatic impact on the world economy, but when you consider the sheer amount of data that is being generated at NASA Goddard alone, "big" doesn't even come close to capturing it. A more appropriate adjective would be "enormous," since we're talking about data archives that deal now with petabytes—thousands upon thousands of terabytes. Not surprisingly, Goddard Space Flight Center is at the forefront of data generation, capturing, processing, analysis, storage, and delivery. Not only are NASA's spacecraft generating enormous amounts of data in both Earth and space observation, but our computer scientists and engineers are busy setting a standard of innovation for how to process and use that data. Indeed, big things are happening at Goddard Space Flight Center in the arena of Big Data.

This issue of *Tech Transfer News* will feature technologies that demonstrate both the breadth and depth of Goddard data expertise. In addition to the scientific and commercial impact of these technologies, this issue will also highlight the profound capacity of Big Data to serve the public and affect social change. A common theme running throughout the interview section is how doing Big Data at the Goddard Space Flight Center means working directly for the good of society.

To get started, we will showcase current projects and their primary applications in space science. Next, we will take a look at some potential applications outside of NASA and the climate science community. We are particularly proud to provide our readers with an expanded interview section, giving voice to some of the leading scientists, engineers, and program managers working with Big Data at Goddard Space Flight Center. You can read about the unique challenges and opportunities in regard to Big Data intellectual property in "Patenting Perspectives;" catch up with two Big Data "SBIR/STTR Success Stories;" and find news pertaining to "Networking and Outreach," along with information on recent patents and Space Act Agreements in the closing sections.

NASA satellites have already provided more than 40 years of Earth observations from space -- a critical, global record that has already proved crucial in helping scientists better understand our dynamic planet.

—PHOTO BY NASA

Big Data at NASA Goddard: New Technologies

Improved Compression and Processing

As observation data continues to be generated by Goddard Space Flight Center at extraordinary rates, the quality of that data will largely determine the application utility and commercial potential. This is especially true for image data, which requires higher quality and improved compression for optimal delivery. Estimated

Spectrum Adaptive Postfilter (ESAP) and Iterative Prepost Filtering (IPF) Algorithms (GSC-14213-1) provide both advantages, using frequency-based, pixel-adaptive filtering for low bit rate JPEG-format images and MPEG-format video. By increasing the signal-to-noise ratio, the ESAP and IPF algorithms can significantly reduce the blocking artifacts that degrade image quality in high compression.

Data compression is critical for the future of Big Data. Without increased processing speed and resolution, data performance and optimization will not be achieved. An advanced version of the Universal Source Encoder for Space (USES) lossless data compression processor has been developed, which offers improved quantization capability in a radiation tolerant field-programmable gate array (FPGA). The new Flight Lossless Data Compression Electronics USES-32 (GSC-17101-1) supports compression at a rate of up to 100 million samples per second, with data up to 32 bits. This is a significant improvement to the current USES, which is limited to 15 bit data and a 20 Msample/sec rate.

Increased data generation means new challenges in data processing and refinement as well, two functions essential for Big Data commercialization. One of these challenges is how to work with nonlinear data, such as water waves and wave evolution. The Huang-Hibert Transform (HHT) Data Processing System (GSC-14591-1) was designed to address the difficultly associated with nonlinear data sets. The PC-based hybrid system demonstrates clear advantages over traditional Fourier-based methods, which cannot adequately translate linear analysis to nonlinear phenomena.

Virtual Climate Data Server (vCDS) and MERRA Analytic Services (MERRA/AS)

One of the most exciting Big Data projects at NASA Goddard Space Flight Center is the Virtual Climate Data Server (vCDS). There is a shift occurring in the paradigm of data analytics and delivery, moving away from client-side processing—where data would be downloaded and processed by the user—and into the realm of Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS) delivery. The fundamental reason for this shift is the enormous size of contemporary data sets; and they are only getting bigger. To streamline productivity and make Big Data more efficient for the user, the processing component is being done where the data resides, so that huge amounts of data do not need to move, thereby saving the user from the time and capabilities necessary to download or input massive data sets.

The vCDS Concept, Design, Architecture, and Operation is described as “a software appliance specialized to the needs of data-centric climate applications” (GSC-16444-1). Along with PaaS and SaaS capabilities, the architecture of the vCDS—taking advantage of enhancements to the integrated Rule-Oriented Data System (iRODS) that manages data and data products—enables a virtualization of the climate server. This opens up avenues for Virtualization-as-a-Service (VaaS): “a capacity to respond in an agile way to new customer requests for data services and a path for migrating existing data services into the cloud.”

There are a number of administrative extensions and analytic tools built into the VaaS architecture and vCDS platform. These enhancements to the iRODS, such as the NetCDF Module, can provide “policy-based control over collection-building, managing, querying, accessing, and preserving NetCDF scientific data sets” (GSC-16445-1). Other extensions help system management by supporting metadata compliance and administrative monitoring (GSC-16446-1), or allow for multiple vCDS software stacks to be automatically built in diverse computing environments (Repetitive Provisioning: GSC-16447-1). All of these vCDS-related technologies benefit NASA’s missions by augmenting the effectiveness of remote sensing and climate modeling capabilities.

MERRA Analytic Services (MERRA/AS)

Along with the shift toward VaaS data delivery through the vCDS system, there are efforts underway to increase the analytic capabilities of data processing at NASA Goddard. The Modern Era Retrospective Analysis for Research and Applications Analytic Services (MERRA/AS) were developed to improve data performance, and also provide more refined data sets to users and customers. MERRA/AS is described as a “cyberinfrastructure resource for developing and evaluating a new generation of climate data analysis capabilities” (GSC-16594-1). Working with NASA’s Observations for Model Intercomparison, the new analytic architecture will reduce the time spent in the preparation of data products for use in scientific and commercial applications. Initial applications for NASA include supporting the Virtual Climate Data Server (vCDS) technology, currently used by the NASA Center for Climate Simulation (NCCS) to deliver Intergovernmental Panel on Climate Change (IPCC) data to the Earth System Grid (ESG).

Similar to the extensions that increase capabilities through the vCDS system, there are a number of Application Programming Interface (API) developments that correspond with MERRA/AS, in order to facilitate and refine data processing and delivery at NASA Goddard. “Persistence Services (PS) allow users to store, download,

The NASA Center for Climate Simulation (NCCS) offers integrated supercomputing, visualization, and data interaction technologies to enhance NASA's weather and climate prediction capabilities. It serves hundreds of users at NASA Goddard Space Flight Center, as well as other NASA centers, laboratories, and universities across the U.S.

—PHOTO BY NASA

annotate, and otherwise manage MERRA Analytic Services (MERRA/AS) codes or scripts that implement the map and reduce functions of their analyses" (GSC-17115-1). Another CDS API creates a Reference Model, Library, and Command Interpreter for uniform control and "harmonization" between system components (GSC-17117-1). These technologies refer to a series of capabilities that are enabled over the vCDS through what is called "MapReduce analytics." The Climate Data Services (CDS) API enables MapReduce to process data with higher performance across scalable data management (GSC-17118-1); for instance, the virtualized system can refine raw data at faster speeds and according to more climate variables, thereby delivering more refined data sets for end-users. The CDS API Client Distribution Package contains the code, tools, and information necessary for end-users to work with the data once delivered over the vCDS (GSC-17116-1). Without these advanced APIs, the MERRA/AS capabilities would not be optimized for such an impressive breadth of potential CDS applications.

New Applications for Climate Data Services

According an article in *Forbes* online, the International Data Corporation and International Institute of Analytics have predicted the 2014 Big Data market to reach $16.1 billion, growing six times faster than the overall IT market.[1] How much of that market might be applicable to NASA Goddard's Climate Data Services is harder to predict, but it is telling that agri-business giant Monsanto spent a reported $1.1 billion to acquire Climate Corporation in October of 2013.[2] Large scale agriculture is just one of the potential applications for data products and services related to climate science.

Climate data also has significant potential for the energy industry. NASA Goddard CDS technologies can help renewable energy efforts by analyzing weather and creating advanced models for predictive investment. Observational data can be extremely useful for traditional energy companies seeking to improve their monitoring systems for oil and gas extraction. Not to mention, NASA data can play a role in the identification of future energy sources and contribute to a more sustainable energy industry overall.

Other promising applications for NASA Goddard's Big Data technologies include land imaging, emergency management, and disaster relief, and insurance assessment.. Coming up in the "Interviews," Goddard computer scientists and engineers will discuss some of the current projects and collaborations with agencies and organizations around the globe dedicated to minimizing the social and environmental impact of natural hazards. While this is an extremely important application in developing countries that still lack resources and infrastructure to adequately handle large-scale disasters, recent climate-related events such as Hurricane Sandy in New York City and the Oso mudslide in Washington State, underscore the importance of improving emergency management in the United States. With the help of a new generation of Climate Data Services and analytic tools, city planners and policy makers can make better and more informed decisions about how to best address the challenges of our changing climate.

For a more in-depth and technical look at some of the individual technologies, underlying architecture, and general strategy for Big Data R&D at NASA Goddard Space Flight Center, we recommend the following reading: "MERRA Analytic Services: Meeting the Big Data challenge of climate science through cloud-enabled Climate Analytics-as-a-Service," by Schnase, Duffy, Tamkin, Nadeau, Thompson, Grieg, McInerney, and Webster; published in *Computers, Environment, and Urban Systems* (2014): http://dx.doi.org/10.1016/j.compenvurbsys.2013.12.003.

1 "$16.1 Billion Big Data Market: 2014 Predictions From IDC And IIA," by Gil Press. Forbes.com, http://www.forbes.com/sites/gilpress/2013/12/03/idc-top-10-technology-predictions-for-2014/. Accessed 10/07/14.

2 "Monsanto Buys Weather Big Data Company Climate Corporation For Around $1.1B," by Alexia Tsotis. Techcrunch.com, http://techcrunch.com/2013/10/02/monsanto-acquires-weather-big-data-company-climate-corporation-for-930m/. Accessed 10/07/14.

BIG DATA AND SPACE WEATHER
Interview with Marlo Maddox

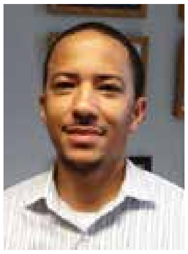
Big Data Interview

Q. ***How did you get involved with the Community Coordinated Modeling Center (CCMC)?***

I started working with the Community Coordinated Modeling Center as a summer student in 2000, when the group had just been established. The group was developing its initial parallel computing capabilities, and I had been doing undergraduate research in Beowulf cluster computing technologies, so it was a good fit. The CCMC was interested in establishing a dedicated parallel computing infrastructure using high performance computing clusters, and needed help with configuring and benchmarking their first cluster. I was involved in configuring the CCMC's first dedicated cluster, enabling the CCMC to perform both space weather modeling.

Q. ***What are the basic functions of the CCMC?***

The group was formed in late 1998-99 to facilitate the development of models for specifying and forecasting conditions in the space environment. There were already a number of active research modeling activities for space weather, but they didn't necessarily translate into operational forecasting capabilities for the US. There was a huge gap between the space weather research community and operational arms of NOAA [National Oceanic and Atmospheric Administration] and the Air Force Weather Agency (AFWA), both of which were the two early collaborators in establishing the CCMC. AFWA invested in the CCMC's first super computer cluster 14-years ago with the ultimate goal of transitioning research models into the capability to issue operational space weather forecasts.



Marlo Maddox

COMMUNITY COORDINATED MODELING CENTER DEPUTY DIRECTOR

Code: 587 / Science Data Processing Branch

Years with NASA: 13

Education:
M.S., Computer Science,
The Johns Hopkins University
B.S., Computer Science,
Morgan State University

There are two main thrusts of the CCMC. The first is to support the space weather research community by hosting a suite of physics-based space weather models that cover the entire Sun-Earth connection. These models are made available to the international community through an innovative Runs-On-Request service that allows anyone in the world to execute world-class simulations on dedicated CCMC super computers. Results/data from all runs are archived and published online for further analysis. The CCMC also provides online advanced scientific visualization tools allowing users to perform very complex simulations and analysis from a common

This summer, 12 participants took advantage of the unique opportunity to explore the burgeoning field of space weather by attending the two week long SWREDI summer boot camp covering the fundamentals of space weather and the basic space weather forecaster training. Training featured the iSWA space environment models installed at CCMC and other analysis tools and was informed by the operational experience of the SWRC service/forecasting team.

—PHOTO BY NASA

web browser. The second thrust of the CCMC is to transition research models to operations. This is achieved through independent validation and metrics activities for all models at that are hosted at the CCMC. Models that can be used for forecasting are run in real-time and evaluated as they execute in an operational environment. There are many useful tools and data that come out of this activity that have proven useful for internal NASA mission operations, specifically in the realm of alerts and forecasts for NASA robotic missions. We now host the largest collection of space weather models in the world, and have developed products that utilize our collection of models running in real-time to provide forecasts for end-users.

We have the ability to run models in a research capacity, and also in real-time operational environments, where those who ultimately want to use the technology can issue forecasts.

Q. *How would you describe the CCMC's relationship with NASA Goddard?*

We are a project run out of the NASA Goddard's Space Weather Laboratory (code 674), that works

through the Heliophysics Science Division (code 670), and ultimately reports to the Sciences and Exploration Directorate (code 600). We are hosted at the Goddard Greenbelt campus and provide space weather predictions to the entire NASA agency. In particular, we work with unmanned robotics missions; although we do have a close partnership with Johnson [Space Center], which runs manned spacecraft missions.

Q. *Does the CCMC collaborate outside of its partnering agencies?*

Oh, very much so! Space weather is an international endeavor, and along with all our sister agencies in the U.S. government, we work with a number of international agencies, such as the Korea Meteorological Administration (KMA) , the UK Met Office, Belgium Institute for Space Aeronomy (BIRA), Korea Astronomy and Space Science Institute (KASI), and Denmark's National Space Institute (DTU Space). We have ties in one fashion or another to any and every space weather stakeholder around the world.

Q. *Can you elaborate on the education and outreach efforts of the CCMC?*

As part of our operational arm that provides forecasting for NASA robotics missions, we also run the NASA Space Weather Research Center (SWRC) providing support for NASA missions throughout the Heliosphere. We also manage the Space Weather Research Education Development Initiative (SW REDI) that offers training for forecasters and engineers across multiple agencies, along with students who participate in forecasting. Each year we host a number of Junior Forecasters, which is a program that has brought students to the CCMC since 2010.

Q. *What are the challenges facing the current state-of-the-art space weather tools?*

The current state-of-art in high performance computing is the beowulf-class parallel computing cluster architecture where individual compute nodes are interconnected creating a very cost-efficient computational environment. We are also exploring the utility of GPU computing which utilizes very powerful graphics processors for numerical calculations.

A primary challenge we are facing is that as we increase our computational power, we generate so much data that storage becomes an issue. Currently, there is no elegant solution for data storage. We can buy lots of disks—and since they are relatively cheap, we can address the problem with brute force—but the main problem is that we can't shift the data around efficiently. We need to move the processing power around to where the data is and allow users to access huge data sets, without having to snail-mail disks. Once we can combine increased processing capabilities and innovative data storage solutions, we will be able to provide remarkable products to the international space weather community.

Q. *What has been most rewarding about your work at the CCMC?*

It is very rewarding to help contribute to space weather modeling and forecasting. Everyone is familiar with tornadoes and hurricanes, but not so familiar with solar flares or geomagnetic storms. Because of the real impact on many technological systems we have become increasingly reliant upon, the goal is to make space weather a part of the general weather report on the evening news, which would contribute enormously to public education. Also, since I'm involved with building specific tools, it's very rewarding to see them in use. I'm particularly proud of a couple of projects, the first being an Integrated Space Weather Analysis (iSWA) system, which is designed to give anyone with an internet connection the ability to access a massive collection of space weather data that can be used for real-time space weather analysis, as well as historical impact analysis. We built this system to enable multiple forecasting capabilities, and also to be used as a resource for both research and education. It is really nice to see the system used in an academic setting, training the next generation of scientists and forecasters.

The second project is lesser known and more behind the scenes and is referred to as the Kameleon Software Suite (GSC-15440-1). We currently host 60+ models at the CCMC, and as you might imagine, the data from these models is in a wide variety of formats. In order to access, analyze, and visualize the data, it needs to be in a standard science data format that can be used across a broad range of end-users. This means creating meta-data and comprehensive descriptions of what you're looking at, so even non experts can use it. I like to use the analogy of going to a big-box electronics retailer to buy a camera, and if each camera had a special image format, it would be extremely difficult to make a decision. Standard image formats are needed to give consumers confidence about the technology, and the same applies for space weather data. We need to standardize data output for space weather tools so users know how to read the results.

Big Data

BIG DATA VISUALIZATION
Interview with Dr. Horace Mitchell

Big Data Interview

Q. ***How did you first become involved with data visualization at NASA Goddard?***

My research background is in physics, and I was working on the ionosphere and magnetosphere at the Naval Research Lab, in large part creating computer simulations. Running the simulations would generate a lot of information, but it was often hard to interpret the data with traditional plot representations. I found it effective to do data visualization and animation for the results. This was just as the early computer graphics workstations were coming out, and I started using the new computers and helping others with more advanced visualizations. A colleague of mine was working at NASA and was involved in the Goddard computer center's plans to build a data visualization program, so he brought me up. That was in 1991.

There were already a lot of people using computer graphics, not only for media purposes, but also in the scientific community. In many ways, scientists have always been doing visualization, whether plotting by hand or on computers. The tools weren't around to do movies yet for scientific data, but the Naval Research Lab had already bought equipment to make films related to their work. So the idea had been around for a long time, but the sophistication and technology still needed to catch up.

Q. ***How does the Scientific Visualization Studio (SVS) work with NASA Goddard to support R&D?***

It's important for me to say that even though I came to NASA to support research, what our group has really been doing is to provide the broader scientific community and the public a means of understanding what goes on at NASA from a science perspective. The Studio does a great deal of outreach and also focuses on education to help promote NASA's mission. Scientific research is a very personal thing; it requires immense questioning and introspection of why particular results exist and what that data means, and that is hard to farm out. What we do is take aspects of what the public might not understand about Earth science, and use what they do know about graphics—how to interpret visual information—and create a product that can wow them with data, but in a way that makes them comfortable with the format. We are ultimately using the same tools as the film and television industry to achieve success with an intended audience that is highly adaptive to new media technologies.

Dr. Horace Mitchell

LEAD, SCIENTIFIC VISUALIZATION STUDIO

Code: 606.4

Years with NASA: 23

Education:
Ph.D., Physics, Rice University
M.A., Physics, Rice University
M.A., Applied Mathematics, Princeton University
B.A., Mathematics and Physics, Rice University

Q. *What projects does the SVS currently have in the works?*

We're not involved with any high-end projects right now, but have been very active with Goddard's Hyperwall, which is a large, multi-screen display designed to travel around to events and conferences for education and outreach. We developed software to take interesting things from NASA-generated data and show them visually all around the world. There are many presentations designed for the Hyperwall that can be viewed on our website, and also available for download [http://svs.gsfc.nasa.gov/]. Additionally, we have developed a free app—the NASA Visualization Explorer—that can be downloaded for iPhone and iPad from our website or the Apple App Store. The app is a conduit for distributing our data visualizations in a palatable manner for consumers. Our group was often doing work for somebody else, and it was difficult to keep up with producing both visualization and web content, so we now have an ability to deliver visualizations and stories directly to the public. It's not just Earth science either, Heliophysics and Astrophysics became interested in our work, so we support multiple NASA science divisions. We're producing two posts a week!

Q. *How does data visualization help make the case for climate change?*

Well, if the visualizations are honestly done, but done in a way to explain core information—and hopefully the public understands this is a logical thing, not just one person's research—then we can create products that both show uncertainty where we still don't know everything about climate change, but also show that we can understand the main factors. There was a study done that explains the "Six Americas" of climate change related to public opinion, ranging from passion on opposite ends of the spectrum, and positions in between. My take on it is that we're not going to change people's minds who passionately don't believe in climate change for economic or political reasons, so we should be

The Hyperwall is a big beautiful "wall" of high-definition screens used to display NASA's latest and greatest data visualizations, images, videos, and other presentation material, and is a primary outreach platform for NASA's Science Mission Directorate. Existing Hyperwall stories highlight themes in Earth science, heliophysics, planetary science, and astrophysics. PowerPoint and Keynote presentations are available for download on each existing topic. The Scientific Visualization Studio developed the Hyperwall software.

—PHOTO BY NASA

targeting what we call the "science aware" public, people who are interested in science and want to understand the structure of how things work. We are certainly not in the market to evangelize, but rather to explain and visualize the great new results of NASA Earth, atmospheric, and space science. We have the capability to explain our current level of understanding related to climate change, and hope to visualize new missions to come.

Q. ***What are the challenges specific to the work of the SVS?***

The earliest challenge had to do with helping people understand data visualization in terms of publishing and publicizing scientific work. Initially, the ability to understand the effect of visualization was very naïve; researchers would understand their data very well, but didn't see how visualization could be used as a helpful tool for public understanding. The premise is not to use visualization to extract more data—we're not trying to analyze scientific work—but to convey the research in a more dramatic way that isn't possible without the technology, or more importantly, the time and enthusiasm to do it alone. We're already set up for this purpose, and it is always great to brainstorm with scientists, providing fresh eyes, to think about the effectiveness of the data and how to bring it to the table in a visual way. Even visual thinkers don't necessarily see right away the impact visualization can make, without having direct examples to demonstrate the potential of their data. Now, we get very exciting responses with researchers and NASA management when we work together, and it has become increasingly clear how vital and powerful a tool visualization can be for policy, promotion, and advocacy of NASA's mission.

The first issue was getting the scientific community to help put together a structure that can work with them and the appropriate media channels. We started out using news outlets, and have obviously moved toward the web and social media, which work to point the traditional media to our visualizations. The second issue is technical, since we still have the problem of wanting to do something but not having the technology yet to make it happen. We keep at it, though; for instance, with flowing oceans and winds, we worked hard to improve the technology and facilitate more sophisticated visualizations. As we speak, we're also working on a data set from a NASA drone that was flown through a hurricane, and we're trying to do visualizations for hurricane winds, which is especially difficult due to the sparse data the drone was able to collect. We need to make a continuous wind-field, and that requires innovation to current technology.

We are also sensitive to avoid pitfalls by being honest in our work and building trust with the public. There have been agencies that have been brought to task for producing propaganda videos, and we would rather educate the public by pulling stories out of the data, instead of evangelizing the science. We do work with the media occasionally to put together a "reporter's package," which helps frame the story, but our primary concern is to be straightforward and help the excitement of the scientists find expression in a visual outlet.

Q. ***What has been most rewarding about your work with the SVS?***

We get a reasonable amount of recognition for the work we do and that makes us proud, but the most rewarding aspect is when a scientist comes back and says to us, "You really helped me tell my story." I give my own talks and frequently speak about our work, but it's even better when those that we have helped use the visualizations in their own talks. We live in a time when visual ideas are so prolific, and people are generating their own movies and shows on YouTube that are very professional; it's very rewarding to know that we can contribute to the impact of science on the visual imagination. We're also not afraid of anybody taking over our work, because there is so much more data out there and so much more to be done!

It's amazing how receptive people have been to our work, and how excited they get. There has traditionally been excitement over manned space flight and exploring the moon; but conveyed in the right way, people get very excited about Earth science! I've enjoyed watching members of our group sit down with movers and shakers in the science world and feel appreciated. Only two of our 12 members have formal backgrounds in science, but everyone has the chance to take real ownership over their work. Typically, in the film or TV industry you'd just be a cog in the machine, but here at NASA Goddard, our visualizers can pursue individual projects that give them a lot of control from beginning to end.

Big Data

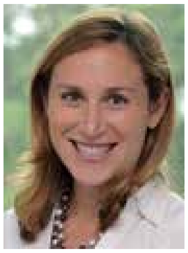
BIG DATA LANDSLIDE MODELING
Interview with Dr. Dalia Kirschbaum

Big Data Interview

Q. How did your research interests lead to working at NASA Goddard?

During my Ph.D. research, which focused on remote sensing and natural hazards (specifically landslides GSC-17221-1), it became clear that a huge gap existed between the understanding of landslides at a local level, and the ability to draw conclusions on a larger scale. There is data available from satellites like topography and precipitation, but the capacity to understand where and when rainfall triggered landslides may happen worldwide has not really been achieved with current models. While working on my dissertation, I got in touch with NASA scientists who were developing a global model to estimate potential landslide activity using a threshold-based approach to see if it was possible to close the gap between local and global landslide assessment.

I came to NASA Goddard as a post-doc for a year, soon after which I became a Civil Servant in the Hydrological Sciences Lab. I started using remote sensing data and land surface models to focus on improving landslide modeling in Central America and the Caribbean. In graduate school I received a NASA Graduate Fellowship and also came to Goddard one summer as an intern, so my transition to working at NASA came quite naturally.



Dr. Dalia Kirschbaum
PHYSICAL SCIENTIST

Code: 617

Years with NASA: 5

Education:
Ph.D., Earth and Environmental Sciences, Columbia University
M.S., Earth and Environmental Sciences, Columbia University
A.B., Geosciences, Princeton University

Q. What projects are you currently working on at NASA Goddard?

My current projects are building off work that has already been underway, namely looking at the potential conditions leading to landslides. The main conditions I am investigating are susceptibility variables like topography and soil properties, rainfall extremes from TRMM [Tropical Rainfall Measuring Mission], and soil moisture. The goal is to develop a decision-tree type platform that can identify areas of potential landslide activity in near real-time. Oftentimes with landslide research scientists tend to develop models that are only used over a very small area or are evaluating past conditions. We're trying to integrate our models with an information systems architecture that allows decision makers to look at rainfall, soil moisture, and other landslide conditions in real-time from both a science and emergency response perspective to use in risk assessment and management.

My work at Goddard has mostly been focused on developing regional models for Central America, so I haven't looked at the U.S. yet, but do anticipate the application of this project within other regions and on a global scale. We want to create models that can provide an approximation of potential hazardous activities, which could have a substantial impact in better understanding and ideally anticipating landslide hazards worldwide. Even the best landslide models in the world still struggle with accurately predicting landslide initiation, even over one hill. In this regional approach, our models will not do a great job at estimating landslides at the meter scale, but may help to provide a broader perspective over thousands of kilometers.

Areas with steep topography, lots of rain and poorly consolidated soils or fractured bedrock tend to be hotspots for landslide activity. As a result, from the perspective of the science community we're not surprised when an event occurs in these regions because landslides are not rare events. But what can be surprising is the impact on a community, such as the recent Oso slide in Washington State. The area definitely had risks, but the impact was so large that it raises questions that are relevant to science, public policy, and emergency management.

Q. *Has NASA Goddard collaborated with any other agencies and/or organizations in this effort?*

Absolutely. We have many ongoing relationships with organizations in our target regions of Central America, including CATHALAC [Water Center for the Humid Tropics of Latin America and the Caribbean], SNET [Servicio Nacional de Estudios Territoriales], and MARN [Ministerio de Medio Ambiente y Recursos Naturales], the latter two from El Salvador. This regional project was funded as part of the SERVIR Science Team, so we work with the SERVIR program office to connect with in-country partners. Our goal is to present an approach to regional entities that we develop together with in-country groups, so that we're matching our modeling capabilities and data streams with services and solutions that make sense on a local level, and can help address specific needs for communities at risk in high impact areas. We are also beginning to do this in the Himalayas, working with an organization called ICIMOD [International Centre for Integrated Mountain Development]. In all of these collaborations, we look to work with partners to develop greater flexibility within a bigger architecture that not only has increased data and modeling capacity, but can also provide a solid framework for the transfer or information to those who need it. We are always looking to find ways to improve the current systems—we don't want to reinvent the wheel—and reach more communities that stand to benefit from NASA data and models.

Q. *What challenges have you faced in your work on natural hazards and landslides?*

One of the biggest challenges is to develop an approach that is dynamic but robust enough to capture the challenges in landslide modeling. We want to integrate as much real-time data as possible, but conditions are always changing on the ground, and our data sources are limited in underdeveloped regions. One issue is the size of the landslides, which can range from the size of a conference room to an area multiple kilometers long. Another issue is that the mechanisms for triggering and the types of the landslide can vary greatly. Our monitoring and modeling activities really push the envelope of what can be achieved at a local scale when dealing with natural hazards. We also know that every part of our efforts is going to be imperfect; for one, we don't know when an event is going to happen; and two, there will always be inaccuracies in the data. We're dealing with terrain that is mostly mountainous and covered in dense vegetation, so obtaining accurate precipitation or soil moisture data is particularly challenging. Our modeling approach is also primarily heuristic rather than deterministic, so we are not modeling how water is directly infiltrating or impacting the surface to cause a landslide. This scientific reality makes it even more important to get the right perspective and leverage available satellite data as much as possible, especially since we don't have ground stations contributing to the data collection in many underdeveloped places where landslides often cause the biggest impacts. Rather than strive toward perfect accuracy, we are focused on raising regional awareness to the types of hazards that can occur and the conditions that create the most risk.

Q. *What has been most rewarding about your work?*

In addition to all the challenges, this type of regional, remote sensing-based approach has never been done before, which makes it difficult but also rewarding. Another part of this project is that we have developed a global landslide catalogue that reports rainfall-triggered landslides around the world. It is the first

After a week of heavy rains, a massive landslide covered the Philippine village of Guinsaugon, killing roughly half of the 2,500 residents. The landslide occurred mid-morning, burying a school full of students. A new early-warning system for landslides that uses NASA satellite rainfall data may save lives in remote mountain villages like Guinsaugon.

—PHOTOGRAPH COURTESY LANCE CPL. RAYMOND D. PETERSEN III, U.S. MARINE CORPS.

open database for landslides of its kind. To date, we have over 6,000 reports that date from 2007 to the present. It's a labor of love, for sure! The catalogue will be available to the public very soon, and people will be able to add their own events and download data for scientific research, hazard assessment and more. In addition to generating the first publically available database, we want to use modeling to raise awareness and facilitate a better understanding of NASA Goddard assets that can help at a local level. People tend to know NASA for what we do in space, but don't know about what we can do on Earth and at a local scale to help society. As cheesy as it sounds, we ultimately want to create resources so people can make decisions that help save lives. Landslides happen everywhere in the world, in every state, and in every country. They are not rare events; thousands of people die every year, and even when we don't hear about or see them, they are still happening.

Q. *What technology transfer opportunities do you see for the landslide data and modeling?*

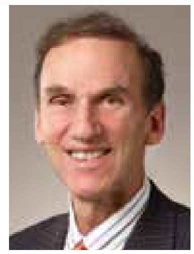
It's very exciting to see new satellite data coming online that will help us understand landslides with greater precision and extended coverage. NASA's Earth Science data products are going to make a big difference in the upcoming years, and we are trying to give a broader perspective and increased situational awareness for how big data can help in both developed and undeveloped regions. Specifically, rainfall data from the Global Precipitation Measurement (GPM) mission and Soil Moisture Active Passive (SMAP) mission will hopefully be game changers in improving the accuracy of our models. All of the landslide work dovetails nicely with flood modeling as well, which is much more complicated; but by putting information in the larger context of risk assessment and emergency management, it is helpful to see the value of our work.

There are certainly opportunities for the use of landslide models in the insurance industry and other private or public sectors where there is a lack of consistent (or any) hazard modeling for landslides. We are also looking to improve our models based on specific conditions such as landslides in burn areas, landslides near or on volcanoes, areas with rapid development and deforestation and other triggers. There are also snow and ice dams that contribute to landslides; really, there are a lot of different ways we can take this. In fact, the more successful we are, the more work we have to do! This is just the first step toward improved modeling capabilities and more information to add into a global landslide hazard information database.

Big Data

BIG DATA AND SENSORWEB
Interview with Daniel Mandl

Big Data Interview



Daniel Mandl

SENIOR COMPUTER ENGINEER

Code: 581

Years with NASA: 34

Education:
University of Maryland College Park, BSEE 1979
George Washington Univ., Masters Engineering Management 1995

Q. *If you were going to tell the story of SensorWeb, how would you start?*

Mark Schoeberl, formerly the Earth Observing System (EOS) Project Scientist back in the 1990's at Goddard, developed prelaunch A-train concepts that would cross strap the Earth Observing System (EOS) afternoon constellation satellites such Aqua, Aura, Calipso and others so that the data could be leveraged for useful societal benefits. He developed two videos entitled Vision 2020 and Vision 2030 to visualize how the public would use this integrated data in similar ways as people use the weather forecast now. Steve Talabac, a technologist in the Software Systems Division at Goddard developed the working definition of SensorWeb and explored a variety of SensorWeb concepts from approximately 2000 to his recent retirement; in particular he developed the concept of automatically supplying key data observation to weather models (such as hurricane track models) from satellites to improve the model in realtime. SensorWeb is a set of sensors (land, marine, air, space) and processing which interoperate in a (semi) automated collaborative manner for scientific investigation, disaster management, resource management, and environmental intelligence.

Our team has been involved with six NASA Earth Science Technology Office (ESTO) Advanced Information Systems Technology (AIST) multiyear research awards which examined various aspects of how to optimize SensorWeb responsiveness and performance. We have used disaster management as our target for our SensorWebs. Furthermore, our team is part of a various international collaborations to extend interoperability with other teams working on similar problems. In the last 11 years, there have been great strides forwards in performance, interoperability standards and responsiveness. We are also poised to leap forward with innovations in hardware and software, focused on getting the best performance from our processors.

Q. *What performance advantages are being specifically targeted for SensorWeb?*

The first thing we wanted to do was to enable scientists and the public to access satellite products without requiring a software team to develop products and an operation team to task the satellite or satellites for the required images. Furthermore, we wanted the satellites to be able to trigger themselves on some occasions, via onboard detections or triggered via other sensors. We built a "do-it-yourself" tool box for our satellite, EO-1. Anyone can point at a map on our website and task EO-1 for imagery and then automatically process and receive selected data products from our cloud.

Our latest effort will begin later in 2015 in an anther award from ESTO AIST-14 in which we will integrate spectrometers and imaging spectrometers onto a mini-quadricopter unmanned aerial system (UAS) and fly this system over agricultural fields, forest land and grasslands in Wisconsin, looking at chemistry and photosynthetic capacity, diversity, disease, GxE (genes by environment drivers of variation) and other items. The idea is to use onboard, intelligent image-aided navigation to optimize our measurements and obtain science grade data with UAS sysFtems. This means that we will use high performance onboard computing to decide where to fly the UAS to optimize our measurements, given that the UAS has about 30 minutes of flight time and thus is a limited resource with very high resolution.

The concepts developed under this research effort and other past efforts will seamlessly translate to other areas of studies that we currently monitor such as volcanos, floods, and landslides. Better observations by the SensorWebs will enable more accurate modeling and predictions for phenomena such as floods (for which we are currently experimenting) droughts, fires, food security and water borne disease.

Q. *What are the major problems or challenges for SensorWeb?*

Even with the great strides forward with onboard processing and improved performance communication links, science and application requirements easily outstrip coverage, spectral resolution, and spatial resolution requirements for the foreseeable future. For example, upcoming NASA Decadal missions that survey the Earth's surface, such as the HyspIRI mission which will survey land surfaces with an imaging spectrometer will generate between 0.6 and 1.2 Gbps of data. Furthermore, depending on which operations concept is chosen, terabits of data are generated every orbit or two. So the sheer volume of future sensors create similar issues onboard as on the ground with "Big Data." This is paired with the issue of limited power to drive the onboard processors. To date, the key solution being implemented is the use of Field Programmable Gate Arrays (FPGAs) which provide an order of magnitude or two better performance onboard using only a few watts of power compared to existing onboard CPUs, albeit with less programming flexibility. Thus, one near term challenge is to provide flexible software Application Programming Interface (API) that enable users to synthesize FPGA circuits as though they were software programs. For the long term outlook, nanotechnology, such as graphene, shows promise in developing multifunctional nanosatellite components that use an order of magnitude lower power, with significant performance increase for processing, sensing and navigation and also can serve as super strong structural material. This would enable nanosat systems that can integrate into the overall SensorWeb architectural concept.

Q. *What is in the future for the SensorWeb program?*

The ultimate SensorWeb goal is to obtain science grade data at all scales and with total coverage of the Earth. Obviously this is not practical. So the next best thing is intelligent gathering of key data that fills in observation holes. This means being able to make decisions based on processing relatively high volumes of data onboard, but with low power. Presently, we are experimenting with multicore parallel processing augmented with FPGA circuits to process selected images/data in seconds rather than minutes or hours at less than 20 watts onboard. But even using only 20 watts for processing makes nanosats not viable for the sensors at high data rates, when one considers the power that small solar arrays can deliver. For our present AIST-11 effort in which we are developing some Intelligent Payload Module (IPM) (GSC-16867-1) onboard processing metrics, we are trying to determine for selected observation scenarios, how much data we can process onboard given satellite and UAS power limitations. Nanotechnology, such as the use of the two-dimensional material graphene might enable transistors and ultimately processors that can perform at 300 gigahertz, but at very low power and weight relative to today's technology. In addition, the technology points to the possibility of super-efficient batteries and solar arrays. Finally, nanotechnology points to the possibility of smaller, more efficient microelectronic machine systems (MEMS) inertial measurement units (IMU). The vision of "smoke detectors in the sky" becomes viable with super light materials that only require minimal power.

Q. *What role can social media play in SensorWeb?*

One of the paradigm shifts that we investigated was the use of social media to enable interoperability within a SensorWeb. Our team helped to develop some international standards for use with SensorWebs in collaboration with the Open Geospatial Consortium

(OGC) which has hundreds of large international partners. It was based on developing standard SOAP/WSDL API so that the internal data process was hidden from an external user and the interface to any participating sensor is abstracted and accessible on the Internet. But we discovered that for 80% of users who are in the ordinary public or are not in a computer related field, it was still too difficult to access satellite sensor data and products. Thus, one of our team members, Pat Cappleare, Vightel Inc., developed the concept of the GeoSocial API (GSC-17162-1), which allows users to find, request and share satellite data and products via social media and other nearly free tools on the Internet. Products can be dropped onto maps and re-aggregated into new products without much technical knowledge. This leverages the sharing functionality built by others around the world to share sensor data in a much easier way. This enables users to easily share key data with a community of people of similar interest, for example flood disaster responders, and use Facebook, Twitter and Github.

Q. *How can NASA Goddard use its growing expertise with cloud-based services in relation to SensorWeb?*

We're looking toward the use of crowd-sourcing capabilities, so that as our data from satellites is uploaded to the cloud, products are automatically produced and shared with a community of common interests. Furthermore, the community can augment the data from the ground using their phones. For example, when mapping a flood, the satellite may map a flood from space with coarse resolution. People on the ground can provide additional observation using the GPS in their phone to validate water locations and thus improve the inundation map in a shared environment on the cloud. Vectors and points can be color coded to identify the source. This is a good way to perform calibration and validation of satellite data to see how well it actually detects a certain phenomenon or enables an algorithm builder to adjust the data processing algorithm via a calibration against ground observation. We want to improve modeling via this approach and make it a cost effective tool. This becomes a composite information system—imagine SensorWeb that's small and yet combines people, constellations of nanosats, UAS's hovering near the ground, devices (iPods, tables, etc.), and small sensors enabled by APIs that can deliver data through social media. Furthermore, one function that we have operational in our cloud is called a Web Coverage Processing Service (WCPS) (GSC-16273-1) which allows users to invent algorithms to process the sensor data either on the ground or on board without having to program anything. Taking that one step further, we are developing the concept of using the cloud to upload key map features to perform selected algorithms.

Q. *Speaking of trends, what do you see making the biggest impact on SensorWeb?*

Autonomy is one key function that I have not mentioned yet. We have autonomy software running on EO-1 which enables it to make independent decisions of what images it will take. This software was developed by JPL under the NASA New Millennium Program with Steve Chien as the lead. Furthermore, members of our team have also done experiments with a distributed architecture of intelligent agent software modules. Thus, a key step is to integrate autonomy software into a SensorWeb which follows what already has been done. The next milestone where we hope to make some strides is the UAS experiments that start this year, and enabling the UAS to make its own decisions as to where it makes measurements based on what it sees with its onboard processing. Of course, in the satellite domain, this type of functionality has been demonstrated using the EO-1 satellite.

Q. *We've covered the past, present, and future of SensorWeb. Is there anything left to tell?*

There are so many ways to tell this story, and it's very much still being written. Space based FPGAs are moving us in the right direction. Nanotechnology points to the possibility of superlight and high performance nanosats. AI points us toward distributed intelligence to dramatically automate networks of sensors and improve our ability to discover fleeting scientific phenomena. I like to use a basketball metaphor: if you're a really good player, you can close your eyes and still make a shot. Your internal senses and intelligence can fill in the holes where the senses are lacking. Your brain acts like a holographic image, using data fusion that is so well integrated that the player can still make the shot. SensorWeb evolution can act the same way enabling the filling of holes in models and enabling better decision support despite lack of total spectral, spatial and temporal coverage.

Big Data

BIG DATA CLIMATE
Interview with John Schnase

Big Data Interview

Q. ***How did you get involved with Big Data at NASA Goddard?***

I work in the Computational and Information Sciences and Technology Office (CISTO), which is a component of the Earth Sciences Division in Goddard's Sciences and Exploration Directorate. CISTO is home for NASA's Center for Climate Simulation (NCCS). The NCCS is a high-performance computing center that supports the climate research activities of NASA scientists, primarily those working in Goddard's Modeling and Assimilation Office (GMAO) and at the Goddard Institute for Space Studies (GISS). Climate research—the modeling aspects of climate research—involves consuming and producing huge amounts of data. It's considered a "Big Data" domain. So working in this area inevitably involves working with Big Data.

John Schnase

CLIMATE INFORMATICS LEAD

Code: 606 (Office of Computational and Information Sciences and Technology)

Years with NASA: 15

Education: PhD Computer Science, 1992, Texas A&M University

Q. ***What work is being done with climate data at NASA Goddard?***

The NASA Center for Climate Simulation provides state-of-the-art supercomputing and data services for weather and climate research. That work is supported by CISTO's Climate Model Data Services group and the group that I work most closely with, Climate Informatics, which is an applied R&D group. Together, we basically help scientists compute climate models and manage their data, and we develop the technologies needed to sustain those efforts. We serve a research community based at NASA centers and laboratories as well as universities across the country and around the world.

Climate models are numerical models that integrate a variety of observational inputs with energy, chemical, fluid dynamical, and sometimes biological equations to simulate the Earth's atmosphere, oceans, land surfaces, and ice. The output from these models can be quite large—hundreds of terabytes in size—and they contain a wide range of variables that characterize the state of the climate at various time steps, around the globe, from the surface of the Earth to the stratosphere. These outputs are important data products in their own right—they're computed data sets every bit as important for some types of research as NASA's observational data. They're used extensively for weather forecasting, climate research, and, importantly, they're used to project future climate change and understand historic conditions of the climate.

Until recently, the data produced by climate models were almost exclusively of interest to the climate research community. In a way, that made our work fairly straightforward, it was work we understood. But with society's increasing awareness of climate change and the impacts of global warming, all of a sudden there's tremendous interest in these data products beyond the research community. Civil engineers in New York City working to design infrastructure to deal with storm water 75 to 100 years out want access to the information generated by climate models. These data products can be used in agricultural forecasts, to assess the risk for wildfire, identify changing patterns of disease spread, assess insurance risk, and many other applications with commercial potential. As the demand for climate model data increases, and the communities wanting access to data become more diverse, the question arises: what's the best way of serving this new and growing community?

Q. ***How can NASA Goddard deliver Big Data to these new applications?***

That's what we're trying to understand. Meeting the Big Data challenges of the climate sciences is pushing us in new directions, changing the way we work. If you step back and think about the traditional scientific data practices in this domain, the approach up to now has been to store large collections of data in archives. To use the data, scientists move a subset of the data, the specific parts they need for their research, to their local workstations where they are then operated upon by analytic tools or programs residing on the workstation. The data sets moved are generally not changed in the process; the modifications needed to use the data are the scientist's responsibility.

But as these collections grow larger, into petabytes-size collections—a petabyte is 1000 terabytes—the old model breaks down because of the sheer amount of data. What if a person needs to download a terabyte of data? That's not all that much these days—a terabyte is 1000 gigabytes—that's the size of my Dropbox account. The average internet speed in the US is now around 10 Mbps (megabits per second). At that rate, it could take up to two weeks to transfer one terabyte of data. What if the analysis needs to be run over the entire collection? Some of our more interesting questions involve looking for patterns within the entire collection. It's impractical to transfer the entire archive to the customer.

Clearly, a new approach is needed. We need to reduce the amount of data that's transferred. There needs to be a way to shift some or all of the analytic work to the storage side of the client/server relationship and move results to the scientist or application rather than large blocks of raw, unreduced data. That's the technical challenge that our Climate Informatics group is trying to address.

The way we're tackling that problem is to first recognize that in our interactions with Big Data, the goal ultimately is to extract useful information. We have an example of how we're doing this in a new service that we've been working on over the past couple of years: MERRA Analytic Services.

MERRA—the Modern Era-Retrospective Analysis for Research and Applications—is a dataset produced by the GMAO. MERRA integrates data from a variety of satellite systems with numerical models to produce a temporally and spatially consistent dataset containing climate variables that are not easily observed. It provides global coverage, and MERRA's time span covers the modern era of remotely sensed data, from 1979 to the present—with a temporal resolution of every six hours! The total size of the MERRA dataset is about 200 terabytes.

Retrospective analyses (or reanalyses) such as MERRA have been important to scientists doing climate change research for a long time. But here's an example of a type of climate model output that's interesting to customers beyond the science community. The breadth of MERRA variables—which include atmosphere, ocean, and land surface products—makes MERRA ideal for use in an expanding array of applications. I like to use the example of studying crop production: if, for instance, you want to look at whether the average temperature, precipitation, and wind speed somehow contributed to Nebraska's lousy corn yield during the 1983 season, those values are buried in the MERRA dataset. Think of what it would take to carve out the data for that coverage area and time span, move it to your desktop, and calculate averages from all of MERRA's six hour estimates before even applying your analysis methods. It wouldn't be easy. Yet that's a simple example of the type of information that people want to extract from MERRA.

With MERRA Analytic Services (MERRA/AS), we employ a fundamentally new approach to delivering these climate model data products. Rather than storing data in large file systems and providing only enough compute power to enable downloads, we store the data in storage clusters—distributed collections of compute and storage nodes that operate like a high-performance "compute-storage fabric"—a platform where fast, parallel operations on the data can occur where the data is stored. On top of this compute-storage fabric, we provide analytic capabilities. In the case of MERRA/AS, we've been using MapReduce as the analytic engine, which basically provides a framework for writing parallel programs for cluster computers. MapReduce is particularly well suited for statistical approaches to data analytics, machine learning, and various types of data mining, but we're fundamentally agnostic about the type of analytic engine that drives the system.

Right now, we've implemented a small collection of simple, commonly used operations, such as computing the minimum, maximum, difference, and average values for MERRA variables over arbitrary spatial and temporal ranges. We call these our "canonical operations." And we provide simple interfaces that allow customers to apply these operations to the MERRA data and transfer reduced products back to the customers making the request. In other words, we've built the technology frame for moving analytics to the server side, and we've reduced the amount of data that needs to be transferred to the client side.

Q. *How can NASA Goddard market these new Big Data advances?*

I'm not sure "market" is the right word. What I believe we're doing is designing new ways for NASA and the NCCS to meet the mission goal of making climate model data accessible and usable to our customers—at a time when the Big Data challenges of climate science are driving a paradigm shift. The overarching perspective we're advancing is Climate Analytics-as-a-Service (CAaaS). CAaaS combines high-performance cloud computing, distributed storage, and storage-side analytics to move much of the work that's traditionally done on the client side to the server side, where it's closer to the data and close to large compute power.

An important aspect of our approach is how we make CAaaS available to customers. We are developing a Climate Data Services API (CDS API)—a web API that enables RESTful client/server interactions. The CDS API is delivered to customers in a distribution package that contains the CDS API library, which implements our canonical operations, a command interpreter for direct interactions with MERRA/AS, and example scripts and programs that use API. With this, customers can write simple scripts that operate on the MERRA data and return results in near real-time. The API is extensible, so these simple operations can be composed into more complex operations, and if these more complex operations are found to be generally useful, they can be incorporated into the API in subsequent releases. This way customers become involved in the continuing development of the service—this becomes a generative, community effort that we hope will feed forward to advance capabilities.

Q. *Does this new model for data analytics and delivery require special relationships with end-users and potential customers?*

That's a good question. In the world of Big Data, it's sometimes hard to draw the line between our responsibilities for providing access and services and the responsibilities that should be with the customer. Clearly, CAaaS potentially sets up a different type of relationship with the customer. It could be that the customer has a complex analysis that has to operate over the entire MERRA collection to detect a subtle pattern in the data, a classic data mining situation. Do they move the entire MERRA dataset to their world and build the infrastructure there to do the work? Probably not. Do they engage technical and scientific expertise at NASA to help them compute their analysis? Maybe. If so, how is that done—from a technical, as well as organizational and operational perspective? These are questions that we don't have the answer to right now. But with MERRA/AS and CAaaS we feel that we have an opportunity now to design solutions.

Q. *What has been most rewarding about your work with Big Data at NASA Goddard?*

The last part of that question is easy to answer. I've worked in all sectors—academic, industry, not-for-profit, and now government—and far and away, my work with NASA has been the most rewarding. We're civil servants, and I like that. Our work is rendered in the public interest—we do science, create knowledge, and create new technologies to benefit society. That's noble work, and I'm proud to be a part of it.

What's most rewarding about working with Big Data? Let me say it this way: I started working in computer science during the early days of hypertext and hypermedia, and I had the good fortune to work with some of the pioneers of the field. Some of the early hypermedia systems were incredibly sophisticated, providing capabilities that would impress people even today. But it wasn't until Tim Berners-Lee introduced the world to what is perhaps the simplest possible model for linking data and using spatial navigation to move through information that the World Wide Web and the internet as we know it today came to be. There are two intertwined lessons in that for me: don't underestimate the power of simplicity, and don't underestimate what can be done through the community construction of a capability—people coming together to solve a problem.

I think there's a sense among those of us working with Big Data is that there are important discoveries to be made when huge amounts of data are examined in their entirety. And that with the right combination of technologies, we can find the simple techniques—the simple hypertext linking mechanisms if you will—that will feed forward though society's use and make enormous problems somehow more tractable. Focusing on the climate is particularly gratifying. I feel like we've done enormous damage to our planet. It's rewarding to help fix it. It seems like the responsible thing to do.

SBIR/STTR Highlight

Assimilation Dynamic Network

In collaboration with MaXentric Technologies, LLC, NASA Goddard has developed a field-programmable network of heterogeneous processing architectures that can offer performance and power advantages when compared to existing technology. This network, called the Assimilation Dynamic Network (ADN), has demonstrated Phase I proof-of-concept success, and is moving into Phase II beta release of FPGA (field-programmable gate array) and ASIC (application-specific integrated circuit) prototypes. The ADN takes advantage of multicore (or "manycore") processors that are both scalable and efficient, which can help reduce power consumption in space-based platforms, while improving throughput and latency, without compromising performance in other areas.

There are many different types of specialized and general purpose processors (CPUs, FPGAs, DSPs, ASICs, etc). Complex high-performance applications often require a combination of several different types of processors (a hybrid system) to make an application operate in the fastest/most efficient manner, but programming a hybrid system can be complicated. The ADN project is developing the underlying infrastructure that will let hybrid components communicate seamlessly and transparently, and present a single simplified programming interface to the user. The use of ADN processing platforms that increase performance and programming flexibility can be advantageous in applications beyond NASA space-based computing. Examples of commercial applications include: Software Defined Radio and Radar, Hyperspectral Data Compression, Surveillance and Reconnaissance, Medical Imaging, Data Center Acceleration, and UAV Image Processing.

OrFPGA: An Empirical Performance Tuning Tool for FPGA Designs

A Phase I STTR collaboration between RNET Technologies, Inc., Argonne National Laboratory (ANL), and NASA Goddard Space Flight Center has laid the foundation for developing a performance optimization tool for FPGA designs. There are hundreds of user defined parameters available to designers when developing an FPGA application. Each of the individual parameters have dozens or hundreds of settings, which yields literally millions of total configuration options for the system. The OrFPGA project is developing an FPGA design tool that will automatically explore the vast set of configuration options based on the designers' performance goals to optimize the design for the specified application. By leveraging an existing tool called Orio—intelligent searching through possible parameter configurations of an FPGA design—the Phase I collaboration was able to demonstrate automation and performance optimization with the OrFPGA tool for space-borne computing architectures.

Moving forward, RNET has established a commercialization strategy for the OrFPGA tool, which is twofold: 1) With the development of a stand-alone tool, the OrFPGA can be licensed to end-users, including NASA Goddard; 2) The techniques developed throughout the course of Phase I and future STTR funding can be licensed to major FPGA vendors, such as Xilinx and Altera. Design optimization capabilities can be integrated into existing FPGA design toolkits as add-on features. This flexible IP approach can maximize commercialization potential and enable multiple revenue streams. RNET is already in contact with Xilinx to form a partnership through their "Alliance Program." Such a partnership will lead to assistance with market penetration, product sales, and distribution, along with resource sharing for technical support, products, technology, and engineering talent.

Big Data

PROTECTING BIG DATA *Intellectual Property*

Patenting Perspectives

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. *What are your impressions regarding Big Data IP at NASA Goddard?*

It's an interesting arena, because there is a confluence going on: on one hand, Big Data is the wave of the future, clearly the way things are going; but the other side is that IP rights are kind of static. The standard right now in the industry is that nobody is claiming rights—the data is there and available, and people who want it are going to take it. At Goddard, the advantage is that we have the right to use a lot of data, but we are trying to figure out what limitations there might be, and whether or not we want to put restrictions on the data.

The good thing about the open atmosphere of Big Data IP is that there are less issues with licensing rights, and that means less infringement lawsuits to worry about! The flipside, of course, is that any ownership rights, which would allow us to steer where the data goes, are hard to establish. The upside to this confluence of IP issues is that the data is out there and freely available, and people know what that means for their research or decision-making needs. Whereas the downside is that folks can take the data, change just a little part, and then claim rights so they can charge for it. It really is a double-edged sword.

Q. *What advantages does NASA Goddard have in the Big Data arena?*

There are a number of reasons why we're a major player here. First, NASA controls the satellites that are collecting the data. Even if the satellites are owned by other agencies, NASA is the prime controlling entity. Not just the control of the satellites, but also the downloading and processing of the data, from hurricanes, to water, landslides, volcanoes, and a host of other Earth observation and climate monitoring sources. The raw data is being gathered, processed, and stored in huge amounts. But as raw data it's not worth very much; it's just ones and zeros. Goddard excels at taking that raw data and making it useful. This creates substantial value for targets like science labs, universities, and policy stakeholders. Right now, everyone gets the data they want. But we are having interesting policy discussions amongst ourselves about where to draw the line. How much do we want to alter the data before getting it out there? And what kind of protection should we have for data that can be considered a Goddard product?

Q. *What type of IP strategy do you envision for Big Data at NASA Goddard?*

We have already had interest from a number of commercial entities that want to use NASA Goddard data, but they want that data more refined, with application-based filters for commercial ventures. These companies are

A NASA computer model simulates the astonishing track and forceful winds of Hurricane Sandy.

—PHOTO BY NASA

very interested in Goddard's Big Data capabilities, so we are working to structure agreements that secure R&D funding for our projects, in exchange for access and data products. There is also a potential revenue source downstream from working with commercial entities to provide customizable data products, which are delivered through a subscription-based fee structure. The exciting thing in this arena is the ability to deliver data on a Software-as-a-Service (SaaS) platform, such as our Virtual Climate Data Server (vCDS) and High Performance Science Cloud (HPSC). As Big Data moves increasingly to the cloud, there will be opportunities for new revenue streams that take advantage of Goddard's capabilities to make data more presentable and more refined for commercial purposes. For example, if a company is interested in the carbon content of soil in a particular region, we can filter the data in specific ways to provide value. As I mentioned, commercial entities are already willing to pay for development of these tools in exchange for access and use.

Q. *What are the IP priorities for technology transfer and commercialization of Big Data?*

The first thing we need to do is protect the property of our technology as it moves from primarily science applications to commercial applications. This means the usual steps of filing patents and also copyright protection. If we don't do that, we don't have anything to draw an investor in; and we need to make it clear that Big Data at Goddard does not just have NASA applications. If a commercial entity is going to write us a check, they are going to demand property rights and protection. Our work on Big Data IP plays a vital role! We have been looking at a couple of projects in particular, including our farm data, which has clear application in big agriculture. This is our first case of how we can make this work, and we sat down to scope it out and plan a strategy that we can apply moving forward. We have filed at least one patent so far, and maybe a second or third. Our goal is to move Goddard data from science to commercial applications.

Q. *What do you think the future holds for Big Data technology at NASA Goddard?*

With interest growing from private entities who want to fund new filters for our data, I think there will be a lot of growth in the array of tools and capabilities developed at Goddard. I liken it to Newton, who had to invent calculus in order to discover gravity. We have great scientists and engineers who continue to develop great tools to get them where they want to go. As the data gets more refined to achieve new science applications, the need to develop new tools with powerful capabilities is ongoing. These tools, in turn, open up new opportunities for commercial applications. Just like calculus, the technology developed in pursuit of greater science is also valuable!

▶ *Student winners of NASA Goddard's Optimus Prime Spinoff Challenge.*

—PHOTO BY NASA

OPTIMUS PRIME Spinoff Production Workshop

(APRIL 24 - 25, 2014, GREENBELT, MD)

Student winners of NASA Goddard Space Flight Center's (GSFC) OPTIMUS PRIME Spinoff Video Challenge visited the center to take part in a special awards ceremony with Center Director Chris Scolese and voice actor Peter Cullen, the man behind the voice of the popular TRANSFORMERS character, OPTIMUS PRIME. The challenge, created by GSFC's Innovative Technology Partnerships Office (ITPO), asks students across the nation to submit a three minute video describing their favorite NASA spinoff story. The first place winners from each category (grades 3-5, 6-8, & 9-12) were then invited to participate in the OPTIMUS PRIME Spinoff Production Workshop at Goddard from April 24-25, 2014. During the awards ceremony the students shared their submitted videos, and were then presented with an OPTIMUS PRIME trophy. The students also created professional Public Service Announcements (PSA) on Goddard spinoffs to be used for the upcoming 2014-2015 challenge launching this summer.

TJ Star

(MAY 28, 2014, ALEXANDRIA, VA)

On May 28, NASA Goddard's Innovative Technology Partnerships Office (ITPO) participated in Thomas Jefferson High School's Symposium to Advance Research (tjSTAR) in Alexandria, VA. Senior Technology Manager Darryl Mitchell spoke to students about Technology Transfer and the upcoming launch of the Goddard OPTIMUS PRIME Spinoff Challenge. The ITPO's interactive

▶ *Senior Technology Manager Darryl Mitchell talks with students about NASA spinoff technologies at Thomas Jefferson High School for Science and Technology.*

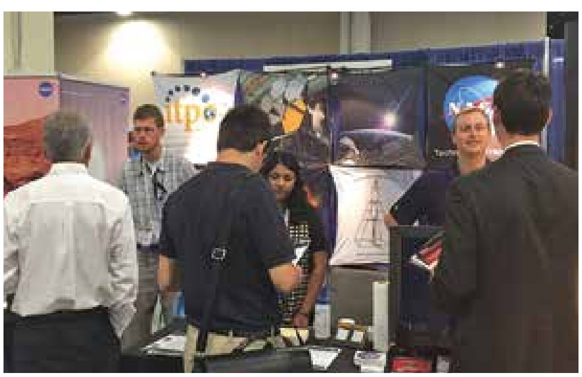
—PHOTO BY NASA

booth featured a thermographic camera which allowed students to see how heat is shown in the infrared, and they also took part in various demonstrations. 800+ students stopped by the booth to learn more about Tech Transfer & NASA spinoff technologies.

TechConnect World Innovation Conference and Expo and National SBIR/STTR Conference

(JUNE 15 – 19, 2014, NATIONAL HARBOR, MD)

NASA Goddard's Innovative Technology Partnerships Office (ITPO) took part in the 2014 TechConnect World Innovation Conference and Expo held in National Harbor, MD. Co-located with the National SBIR/STTR Conference, TechConnect is the world's largest multi-disciplinary multi-sector conference and marketplace of vetted innovations, innovators and technology business developers and funders. The ITPO spoke with attendees about potential partnerships and licensing opportunities, and demonstrated NASA Goddard's Lotus Coating, Molecular Adsorber Coating and Micro-shutter technologies. NASA Goddard's Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) office was also present to speak with attendees about SBIR/STTR opportunities available at NASA Goddard.



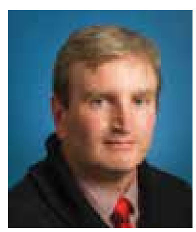
▶ *NASA Goddard representatives speaks with attendees at the 2014 TechConnect World Innovation Conference and Expo and National SBIR/STTR Conference.*

—PHOTO BY NASA

NASA Tech Briefs Webinar

(JULY 17, 2014, GREENBELT, MD)

▶ *Keith Gendreau*



▶ *Darryl Mitchell*

Dr. Keith Gendreau (Code 662), principal investigator of the upcoming NICER Explorer mission of opportunity on the International Space Station, presented a webinar hosted by the Innovative Technology Partnerships Office (ITPO) and Tech Briefs Media Group, on Thursday, July 17, 2014. The webinar, titled "Exploiting the Time Domain in X-rays: The Modulated X-ray Source and its Diverse Applications," discussed the Modulated X-ray Source (MXS), a miniature, low-power, lightweight, and rugged X-ray source that can be arbitrarily modulated in intensity from completely off to full intensity on nanosecond timescales, for a broad range of X-ray energies. NASA applications include calibration of cameras for future space-based X-ray telescopes. For use on Earth, the MXS promises precise dose control for medical X-ray applications and novel analysis techniques in industrial and laboratory settings. The webinar also featured a discussion by ITPO Senior Technology Manager, Darryl Mitchell (Code 504) on the exciting technologies being developed at Goddard for NASA missions.

NASA Goddard Science Jamboree

(JULY 17, 2014, GREENBELT, MD)

The Innovative Technology Partnerships Office (ITPO) participated in NASA Goddard's Science Jamboree on July 17, 2014. Hosted by Code 600, the Science Jamboree featured displays and demonstrations from all science divisions and offered 3D movies in the Scientific Visualization Studio screening room and spectacular presentations on Goddard's Hyperwall. The ITPO's featured theme was "I am innovation" and distributed materials including facts on submitting NTRs, SBIR/STTR success stories, recent issues of Spinoff and Tech Transfer magazines and the upcoming launch of the Goddard OPTIMUS PRIME Spinoff Challenge. Special innovator alter ego cards were developed as an interesting & fun way to educate GSFC about ITPO. The cards, similar to trading cards, highlighted a GSFC-specific technology & referenced GSFC innovators in the context of a superhero with special powers. They were very popular with those that stopped by to learn more. Another highlight of the event continued with the "I am innovation" theme. A special backdrop with the NASA & ITPO logos, complete with a red carpet, was set up for people to take pictures. The pictures were placed in a custom frame recognizing them as an innovator and included ITPO information on the back.

ITPO staff member Dale Clarke speaks with an Intern at the Code 600 Science Jamboree.

—PHOTO BY NASA

NASA Goddard Center Director Chris Scolese visits the ITPO table at the Code 600 Science Jamboree.

—PHOTO BY NASA

The Commerce of Small Satellites Conference

(AUGUST 2 – AUGUST 7, 2014, LOGAN, UT)

The 2014 Commerce of Small Satellites Conference was held in Logan, Utah, from August 2 to August 7, 2014, in the Taggart Student Center at Utah State University. The conference consisted of over 130 exhibitors from 25 different countries with more than 1400 participants in attendance. Exhibiting companies were heavily involved in the development and marketing of Small Satellites and related technologies. NASA Goddard Space Flight Center's (GSFC) Innovative Technology Partnerships Office (ITPO) was on hand to speak with attendees about NASA's role in today's SmallSat/CubeSat market, and the many opportunities available at NASA GSFC in the SmallSat field. Representatives from Goddard attended showcases on Small Satellite development to speak with potential partners and identify strategic enabling technologies.

Technology Disclosures

Disclosures

- BOOST EMBEDDED SOLAR PANEL
- NETWORK COUNTDOWN TIME PROTOCOL
- FAULT TREE ANALYSIS JAVASCRIPT API
- REAL TIME DATA VIEWER
- UNCONDITIONALLY STABLE LOW DROPOUT LINEAR REGULATOR
- THIN-FILM PRESSURE SENSORS FOR USE IN HARSH ENVIRONMENT APPLICATIONS
- NASA OPERATIONAL SIMULATOR (NOS) MOTION (NMOTION)
- NASA OPERATIONAL SIMULATOR (NOS) COMMON
- QEMU MODEL FOR BAE RAD750 (BOARD MODEL)
- SOFTWARE TO CONVERT THERMAL GEOMETRICAL MODELS BETWEEN ESARAD AND TSS
- ITC DEVELOPMENT TOOL SUPPORT PLUG-INS
- 2194141_3X4X1 ELECTRICAL BOX, 3A BUCK REGULATOR
- HIGH-PERFORMANCE SCIENCE CLOUD (HPSC) THE ABOVE SCIENCE CLOUD
- DELLINGR 6U CUBESAT AETD/HELIOPHYSICS SKUNKWORKS
- MINIATURIZED RADIATION HARDENED BEAM-STEERABLE GPS RECEIVER FRONT END (NNX12CA35C)
- SPACE - FLEXIBLE RECONFIGURABLE AND MODULAR ELECTRONICS (SPACEFRAME)
- X-RAY PHOTON AND RELATIVISTIC EFFECTS SIMULATION SYSTEM (XPRESS)
- CORRELATED SINGLE PHOTON PROCESSING ALGORITHM
- ETCH PROCESS FOR SUPERCONDUCTING TIN AND NBTIN THIN FILMS
- COMPACT INTEGRATED TIME-ORBITING POTENTIAL AND MAGNETO-OPTIC TRAP
- DYNAMIC ON-CHIP FLOW AND TEMPERATURE SENSOR
- ELECTROSTATIC PULSED ACTUATION OF MICROSHUTTER ARRAYS
- OPEN GEOSOCIAL CONSUMER APPLICATION
- HEIGHT ABOVE NEAREST DRAINAGE USING USGS HYDROSHEDS AND OPENSTREETMAP DATA
- MICRO-LID FOR SEALING SAMPLE RESERVOIR FOR MICRO-EXTRACTION SYSTEMS
- FABRICATION OF MICRO-LIQUID CHROMATOGRAPHY THERMO/ ELECTROSPRAY MICROFLUIDIC CHIP FOR THE ORGANICS ANALYZER FOR SAMPLING ICY SURFACES
- ALGORITHM FOR DETERMING SOLAR ASPECT FROM IMAGES GENERATED BY THE PITCH AND YAW ASPECT SYSTEM OF THE HIGH ENERGY REPLICATED OPTICS TO EXPLORE THE SUN BALLOON PAYLOAD
- OBJECT-ORIENTED FITS FILE INTERFACE SOFTWARE FOR MATLAB

- VECTORIZATION OF GLOBAL FLOOD MONITORING SYSTEM USING TOPOJSON
- ULTRA WIDEBAND DUAL POLARIZED STACK PATCH PHASED ARRAY ANTENNA WITH HIGH PORT ISOLATION AND CROSS POLARIZATION FOR L-BAND SYNTHETIC APERTURE RADAR APPLICATIONS.
- PHOTONIC ANTENNA ENHANCED FOCAL PLANE ARRAY WITH ALGAAS PASSIVATION
- VECTORIZATION OF NRT GLOBAL MODIS FLOOD DATA USING TOPOJSON
- MYSTRAN
- ORFPGA: AN EMPIRICAL PERFORMANCE OPTIMIZATION TOOL FOR FPGA DESIGNS
- FUNCTIONALIZED NANO-FILM MICROCHANNEL PLATE: A SINGLE HIGH ASPECT RATIO DEVICE FOR HIGH RESOLUTION, LOW NOISE ASTRONOMICAL IMAGING
- MULTI CHANNEL DIGITIZER CHIP
- LINK BUDGET OPTIMIZATION AND COMMUNICATIONS PLANNING TOOL WITH DATABASES OF NASA COMMUNICATIONS ASSETS
- VISUAL INSPECTION POSABLE INVERTEBRATE ROBOT (VIPIR) SYSTEM FOR SPACE APPLICATIONS
- ASSIMILATION DYNAMIC NETWORK (ADN)
- GENERAL MISSION ANALYSIS TOOL (GMAT)
- A LIBRARY AND PARSER FOR SIMPLE INTERFACES BETWEEN JAVA NATIVE APPLICATIONS AND LEGACY C++ APPLICATIONS
- AN INTERACTIVE GRAPHICAL TRAJECTORY MANIPULATION ENVIRONMENT FOR OPTIMAL AND SUB-OPTIMAL SOLVERS
- AN ENHANCED TARGETING FRAMEWORK FOR ADDRESSING INTERIOR AND MISSION LEVEL CONSTRAINTS
- A JAVA BASED PROCESS CONTROL GRAPHICAL INTERFACE FOR MULTI-PHASE SOLVERS
- A JAVA NATIVE INTERACTIVE 3D ENVIRONMENT FOR TRAJECTORY DESIGN
- ENHANCING SENSITIVITY OF CHEMICAL SENSORS BY INTEGRATING WITH A SELF-CONTAINED PRE-AMPLIFIED PRINTED CIRCUIT BOARD
- GODDARD MISSION SERVICES EVOLUTION CENTER (GMSEC) CRITERIA ACTION TABLE (CAT) 5.5
- GODDARD MISSION SERVICES EVOLUTION CENTER (GMSEC) COUNTDOWNCLOCK (CC) 2.0
- OPTIMUM SWATH DATA READER LIBRARY FOR SCIENCE DATA OF EARTH OBSERVING SYSTEM MISSIONS (OPSEEDAT)
- FORTRAN TESTING AND REFACTORING INFRASTRUCTURE
- LAND SURFACE DATA TOOLKIT (LDT)
- NUCLEAR POWERED ROCKET FOR SPACE SHIP
- NOVEL CRYOGENIC MOTOR
- AN ULTRA LOW POWER CRYO-REFRIGERATOR FOR SPACE
- EFFICIENT RADIATION SHIELDING THROUGH DIRECT METAL LASER SINTERING
- GIOVANNI - A TOOL FOR ONLINE EXPLORATION OF EARTH SCIENCE DATA
- ADVANCED OPTICAL METROLOGY FOR XRAY REPLICATION MANDRELS AND MIRRORS
- INCORPORATING EDGE INFORMATION INTO HSEG
- TOOL FOR CUBESAT/ SMALLSAT DESIGN SEMICONDUCTOR PART SELECTION WITH REGARD TO RADIATION EFFECTS
- NON-CLADDING MULTI-MODE FIBER & PRECISION GLASS TUBE
- SPACEWIRE 2014
- SMALL ROBUST COUNTER FOR QUANTITATIVE DETECTION OF PHYTOPLANKTON IN WATER OR DETECTION OF OTHER PARTICLES IN VARIOUS LIQUIDS
- NOVEL HIGH-ACCURACY ULTRA-MINIATURIZED STAR TRACKER
- GAS ABSORPTION MEASUREMENTS USING LASERS MODULATED WITH RETURN-TO-ZERO PSEUDO-NOISE CODES
- SATURN NET FLUX RADIOMETER (SNFR)

- METHODOLOGY OF GENERATING NEAR-EARTH ASTEROID (101955) BENNU SURFACE TEMPERATURES MAPS FOR OSIRIS-REX SPACECRAFT AND INSTRUMENT THERMAL ANALYSES
- A HIGH SENSITIVITY SURFACE-REFLECTANCE LIDAR SPECTROMETER
- A RADIATION HARDENED 12-BIT ANALOG-TO-DIGITAL CONVETER APPLICATION SPECIFIC INTEGRATED CIRCUIT
- GODDARD RADIO-FREQUENCY EXPLORER RADIO FREQUENCY INTERFERENCE REAL TIME DISPLAY SYSTEM (GRID)
- PHOTONIC INTEGRATED CIRCUITS: ADVANCED OPTICAL SENSING WITH A RECONFIGURABLE ARRAY OF OPTICAL DEVICES ON A CHIP
- GODDARD'S RECONFIGURABLE SOLID-STATE SCANNLING LIDAR (GRSSLI)
- BLACK MOLECULAR ADSORBER COATING SYSTEM (MAC-B)
- DATA INTERFACE AGNOSTIC INTER-FPGA EMBEDDED SYSTEM PROCESSOR BUS BRIDGE
- REAL TIME LIDAR SIGNAL PROCESSING FPGA MODULES
- USING PARAFFIN PHASE CHANGE MATERIAL TO MAKE OPTICAL COMMUNICATION TYPE OF PAYLOADS THERMALLY SELF-SUFFICIENT FOR OPERATION IN ORION CREW MODULE
- PULSAR PHOTON EVENT SOFTWARE SIMULATOR
- RADIATION HARDENED HIGH VOLTAGE QUAD-CHANNEL AMPLIFIER
- IMPLEMENTATION OF A MINIATURIZABLE HIGH PERFORMANCE FIBER OPTIC GYROSCOPE FOR SMALL SATELLITES
- AN X-RAY NAVIGATION END-TO-END SIMULATOR
- GMSEC (SPACE MISSILE COMMAND) SECURE API 3.3
- NASA WRANGLER
- MICRO SCALE ELECTRO HYDRODYNAMIC (EHD) MODULAR CARTRIDGE PUMP
- HILBERT SPECTRAL ANALYSIS FOR 2-DIMENSIONS
- LANDSLIDE HAZARD AND FORECASTING SYSTEM
- A MODULAR, HIGH REP RATE SOLID STATE LASER DESIGN FOR MULTI-APPLICATION REMOTE SENSING
- COMMAND & DATA HANDLING FOR THE MAGNETOSPHERIC MULTISCALE MISSION
- HIGH BANDWIDTH WIDE FIELD OF VIEW ULTRA SENSITIVE RADIATION HARDENED SHORT WAVE INFRA-RED (SWIR) RECEIVER
- INTEGRATED RADIATION HARDENED RADIO FREQUENCY DIGITIZER AND SIGNAL PROCESSING ELECTRONICS
- DIRECTLY MODULATED RADIATION HARDENED SHORT WAVE INFRA-RED (SWIR) PULSED FIBER LASER
- AN ENERGY-EFFICIENT NETWORK ARCHITECTURE FOR LOW DUTY-CYCLE FOR WIRELESS COMMUNICATION NETWORKS (NNX12AO54G)
- NANOSAT STAR SCANNER (SS NANO)
- GMSEC ALERT NOTIFICATION SYSTEM ROUTER (ANSR) VERSION 4.0. AN UPDATED VERSION OF A PREVIOUSLY REPORTED SOFTWARE WITH ID# 5027754
- GODDARD MISSION SERVICES EVOLUTION CENTER (GMSEC) REUSABLE EVENTS ANALYSIS TOOLKIT (GREAT) 3.0
- DISCRETE COSINE TRANSFORM (DCT) MINIMUM MEAN SQUARE ERROR (MMSE) PREDICTIVE CODER (DMPC)
- LASER ARCHITECTURE AND ATOMIC FILTER FOR DAYTIME MEASUREMENTS USING A SPACEBORNE SODIUM LIDAR
- DEVELOPMENT OF A SODIUM LIDAR FOR SPACEBORNE MISSIONS
- MPROVED PERFORMANCE OF THE JPEG ESTIMATED SPECTRUM ADAPTIVE POSTFILTER (JPEG-ESAP) AND COMPARISONS TO JPEG-2000 IMAGES
- HAMMER 1.0
- SELECTIVE POROUS SI ANODIZATION AND SI ETCH TECHNIQUE

- SAFETY INHIBIT TIMELINE TOOL
- LANDSAT SCALABLE INTEGRATED MULTI-MISSION SIMULATION SYSTEM (LSIMSS) / COMMAND (CMD) AND TELEMETRY (TLM) PROCESSOR (CTP)
- GROUND OPERATIONS-WEB (GO-WEB): OFFERS AN ONLINE PLATFORM FOR REQUESTING, PLANNING, SCHEDULING, AND CARRYING OUT RANGE OPERATIONS.
- SPHERICAL OCCULTER CORONAGRAPH CUBESAT (SPOC CUBE)
- PIN DRIVER TOOL
- CONTROLLED THERMAL EXPANSION ALLOYS
- SEA5: SPACE ENVIRONMENT AUTOMATED ALERTS & ANOMALY ANALYSIS ASSISTANT
- VHSIC HARDWARE DESCRIPTION LANGUAGE (VHDL) FOR DEMISEABLE REACTION WHEEL
- REACTION SPHERES FOR MULTI-AXIS ATTITUDE CONTROL AND ENERGY STORAGE ON SMALL SATELLITES
- ALLOY THAT MATCHES THE CTE OF SINGLE CRYSTAL SILICON FROM 10C - 30C
- OXIDE DISPERSION STRENGTHENED INVAR FASTENERS FOR CRYOGENIC FASTENING
- HYBRID ARCHITECTURES THAT COMBINE AM, MMCS AND TAILORED CTE MATCHING
- INVAR METAL MATRIX COMPOSITE
- NON-RESONANT FORMALDEHYDE LASER-INDUCED FLUORESCENCE
- ALLOY THAT MATCHES THE CTE OF D263 SCHOTT GLASS FROM 10C - 30C
- ADDITIVE MANUFACTURING OF INVAR
- NEAR RANGE MULTI-BEAM LASER ALTIMETER
- THE SWI(/BAT HARD X-RAY TRANSIENT MONITOR: SEVEN YEARS AND 247 SOURCES, STILL GOING STRONG!
- GAME CHANGING USAGE OF POWER GRID AS AN EXTREMELY LARGE ANTENNA FOR GEOPHYSICAL IMAGING

Patent Applications Filed

- PHASE OCCULTED VISIBLE NULLING CORONAGRAPH
- INDEPENDENT TEST CAPABILITY (ITC) SYNCHRONOUS BUS (ITCSB)

Provisional Patents Filed

- VECTOR NETWORK ANALYZER CALIBRATION FOR QUASI-OPTICAL DUAL-PORTS
- MINIATURE RELEASE MECHANISM OR DIMINUTIVE ASSEMBLY FOR NANOSATELLITE DEPLOYABLES (DANY)
- “MINIATURE, RUGGEDIZED OPTICAL ZOOM LENS“

Patents Filed

- A HIGH EVENT RATE, ZERO DEAD TIME, MULTI-STOP TIME-TO-DIGITAL CONVERTER APPLICATION SPECIFIC INTEGRATED CIRCUIT
- MINIATURIZED LASER HETERODYNE RADIOMETER FOR CARBON DIOXIDE (CO2), METHANE (CH4), AND CARBON MONOXIDE (CO) MEASUREMENTS IN THE ATMOSPHERIC COLUMN.
- PHOTONIC CHOKE-JOINTS FOR DUAL-POLARIZATION WAVEGUIDES
- LOW CONDUCTANCE SILICON MICRO-LEAK FOR MASS SPECTROMETER INLET
- ENSEMBLE DETECTOR
- A METHOD FOR DEVELOPING AND MAINTAINING EVOLVING SYSTEMS WITH SOFTWARE PRODUCT LINES
- VECTORIZED REBINNING ALGORITHM FOR FAST DATA DOWN-SAMPLING

Agreements

COMPANY	AGREEMENT TYPE	PARTNERSHIP ABSTRACT
The Aerospace Corporation	*Space Act Agreement*	*To support the GPS Antenna Characterization Experiment (GPS ACE), collaboration between the Aerospace Corporation and NASA Goddard Space Flight Center through respective IR&D proposals to collect and analyze observations from GPS side lobe transmissions to a high-altitude satellite using highly sensitive GPS receivers installed at a ground station. The GPS spectrum observed at the satellite is sent to the ground site for limited use in mission-specific applications. The availability of the full set of GPS signals at the ground station represents a unique opportunity for thorough analysis of in-flight performance of side lobe signals â€“ signals that are not available through direct line-of-sight to GPS antennas on the ground. Thus, by tying into an existing data stream, this research aims to extensively calibrate the side lobe signals through collection of observations from the entire constellation over a long period of time. This data set will be unique and offer many opportunities for varied analyses to improve our understanding of different aspects of the system, such as signal power and pseudorange accuracy as a function of off-boresight angle, as well as verification of performance assumptions made in GPS simulations. The end results would enable more effective and accurate use of GPS for navigation of high-altitude satellites.*
Rolls-Royce Corporation	*Space Act Agreement*	*Rolls-Royce and NASA wish to develop braze joint performance prediction methods for critical structures subjected to complex loading conditions. Rolls-Royce selected NASA for the partnership because of its knowledge of Failure Assessment Diagram (FAD) based on Coulomb-More failure criteria to predict structural failures in critical brazed joints. Roll-Royce will benefit with NASAâ€™s support to establish braze FAD to define acceptable stress combinations and margins of safety of braze joints and braze repair structures. NASA would benefit from this collaboration by verifying its FAD methodology for failure prediction of structural brazed joints on real industrial application. Roll-Royce also contacted NASA because there is no such existing method available in the industry. Rolls-Royce will use the Methodology of Evaluating Margins of Safety in Critical Brazed Joints (NTR GSC-16042-1) develop at Goddard to help in the performance prediction of brazed joints.*
University of Florida	*Space Act Agreement*	*The purpose of this agreement is for NASA GSFC and the National Science Foundation's Center for High-Performance Reconfigurable Computing (NSF CHREC) to continue their work together on NASA GSFC's ongoing effort to conduct On-Orbit Radiation Hardened by Software (RHBS) technology experiments aboard the International Space Station using the SpaceCube v1.0 board.*

—IMAGE BY NASA/GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO

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

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Send suggestions to Robert.S.Leonardi@nasa.gov.

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