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Investigating Climate Change

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One year ago, the National Academy of Sciences released a report urging NASA to rebuild its aging network of environmental spacecraft by funding 15 Earth-observing satellite missions between 2010 and 2020. Since its release, the decadal survey has galvanized many across the Earth science community. In this issue,

Peter Hildebrand, the new deputy director of the Sciences and Exploration Directorate, talks about the survey's impact on the Earth science community. This issue also spotlights a variety of Earth-observing technologies and applications as well as a concept for one survey-recommended mission.

One on One with Peter Hildebrand, Deputy Director, Sciences and Exploration Directorate

Photo Credit: Chris Gunn

What impact has the first-ever decadal survey on Earth science had on the science community?

The decadal survey is a landmark event. In the past, the Earth sciences have not gotten together to outline their priorities and now we've done that. This report maps the types of missions we fly and the measurements we need to understand the dramatic changes we're seeing in the climate. It provides a roadmap for a sequence of missions that extend from where we are now to where we'll be in the next decade in our attempt to understand and respond to the impacts of climate change. These missions also will improve weather forecasting and help us to assess the global water cycle and the health of the biosphere and to predict biospheric changes. These are important issues. The decadal survey team did an excellent job of selecting, prioritizing, and setting a timeline for these missions. We now need to move forward with the first wave of recommended missions. Of course, that leaves the NASA hierarchy and Congress in the position of figuring out how to fund these missions, but they need to do this.

What trends do you foresee that could affect the funding?

Well, obviously the cost of doing all these things is going to be something that will be an issue. But on the other hand, the EOS satellites were billion-dollar missions; they were big, they were complicated, and they have been extremely successful. Just look at what we've learned about weather, climate, the biosphere, and more. There's no reason why NASA should shy away from this list of missions. They are important and we, NASA, have proven that we can do them with spectacular results. Because of what we've done before, we now have a greater understanding of how the Earth works. At the same time, we must be diligent about developing innovative ways to cut mission costs and introduce greater efficiencies.

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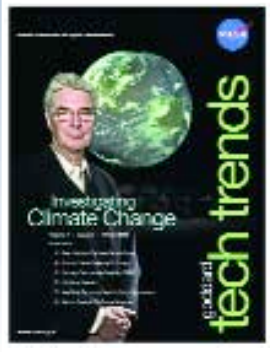

About The Cover:

Peter Hildebrand, the new deputy director of the Sciences and Exploration Directorate, is pictured here in front of the Visitor Center's highly popular "Science on a Sphere" exhibit, which he was instrumental in developing. He talked with Goddard Tech Trends recently about the impact of the first-ever decadal survey on future Earth-observing missions.

Photo Credit: Chris Gunn

Peter Hildebrand... Continued from page 2

How has the decadal survey affected Goddard's priorities?

The decadal survey has affected Goddard's priorities, and the priorities of other NASA Centers as well, by providing this clear roadmap. In my view, the top Earth science priorities after GPM (Global Precipitation Measurement) and LDCM (Landsat Data Continuity Mission) are ICESat-II (Ice, Cloud, and land Elevation Satellite) and SMAP (Soil Moisture Active Passive). For SMAP, we're partnering with JPL (Jet Propulsion Lab) by building the radiometer and providing data analysis and science. I hope we start those missions this spring. Earth science really needs them. They are the best missions to start with because they are mature and ready to go. Also high on the list is DESDynI (Deformation, Ecosystem Structure and Dynamics of Ice). Farther down the road is ACE (Aerosol-Cloud-Ecosystems) and GRACE II (Gravity Recovery and Climate Experiment). We'll have major roles on those missions, too. The power of the decadal survey is that it was carefully thought out and represents a consensus as to priorities. We just need the green light to get going.

With the decadal survey in mind, are there any specific areas where you want to partner with others to develop new missions or technologies?

It's inevitable that a large number of these missions will have partnerships. Some are natural for Goddard and others are natural for other Centers to lead. SMAP and DESDynI are obvious examples. SMAP has a mature team, with the JPL providing mission leadership and Goddard providing the radiometer, to say nothing of the excellent community involvement. As for DESDynI, JPL has been working on an InSAR (Interferometric Synthetic Aperture Radar) concept for years. So they'll definitely want to be doing that. Goddard also will be an important player, supporting the biospheric aspects of the mission. As these and other missions move along, various groups will naturally form, and I expect that Goddard will have strong participation in many of these missions.

What can Goddard do to win these missions?

One thing that Goddard has already done is to improve the management of our Internal Research and Development (IRAD) funds. We've improved the focus on the decadal survey missions and other mission opportunities, and we've focused on cutting-edge new instrumentation concepts. We've improved the quality of management's role in the evaluation process, which has led to a noticeable change in the quality of the projects and the alignment of those projects with the big goals. As we look down the list of decadal survey missions, it's important for Goddard to keep taking a long-term view of what we should do and to think more strategically about what we partner and what we compete. I also wish we had a larger pool of IRAD money; it would be well spent.

What specific technologies do you think we need to work on?

There is a whole spectrum of technologies that Goddard has pioneered — technologies that we need to keep working on. These include passive and active microwave, lidar, and altimetry. We need measurements in the multispectral — visible through thermal — and more. The need for these technologies has only intensified. The demand now is for improved, higher-resolution, higher-accuracy measurements. Let me name a few specifics. We have a strong history with radars, particularly with ground-based and airborne weather radars, and we're particularly strong in the science application. Our engineering capabilities are growing and getting stronger, as are our lidar activities, but we could improve through more cohesive, better-coordinated projects. Doppler lidar technologies are important areas for improvement; improved chemical constituent measurements might be helpful. Laser altimetry is being applied to ice topography changes and to measuring biospheric and ecosystem changes. Combining laser and multispectral measurements is another promising area for understanding the biosphere.


Photo Credit: Chris Gunn

What can we do to stimulate more interaction between the sciences to create significant leaps in science or technology?

I would like to see the Goddard seminar series expanded. I'd like to see more management-level presentations and more publicity about these events. Our current seminar series are great, but a lot more is going on and we have a lot of the experts right here. This would be helpful in learning more about what the other parties do. Building the new sciences building should help, too, because it will eliminate many of the existing geographical barriers. Perhaps we also should have some prizes for scientists who have the courage to leap into new areas of investigation. ◆

Going Beyond the 'A' Train

Goddard Scientist Develops Concept for Future Climate Change Mission

To understand why the climate is changing, scientists say they need to understand the role of aerosols, such as desert dust, in precipitation and cloud formation.

By all estimates, the Aerosol-Cloud-Ecosystems (ACE) mission is probably the most expensive of the 15 NASA satellite systems recommended by the National Academy of Sciences in its first-ever decadal survey of next-generation, Earth-observing spacecraft. But to some Earth scientists, the data that ACE could gather is the linchpin to understanding what is actually causing climate change.

Among those are Goddard scientist Mark Schoeberl, who led a team funded by the Center's Internal Research and Development program to outline a possible mission, and Bob Connerton, chief engineer for Goddard's Earth Science Division. In October, Schoeberl released his mission recommendations in a white paper requested by NASA Headquarters, which also requested mission concepts for the other Academy-recommended missions.

Because of Schoeberl's work, "we now have a good idea of what ACE will really cost and that it's the right science," Connerton says. "It attacks the driving causes of climate change. It goes to the question of why."

The proposed mission Schoeberl and his team conceived features six passive and active sensors either flying on the same platform or in close formation in a 650-km orbit, chosen because it provides 2-day global coverage. Included are an advanced multi-beam lidar, a dual-frequency radar, an advanced multi-band spectroradiometer, and an imaging polarimeter. Schoeberl's team also concluded that ACE should include both high- and low-frequency submillimeter radiometers (see related story on page 5).

Answering the Aerosol Question

These instruments, he says, will help answer the consuming question of why the climate is changing. "For climate forcing, we need to understand the role of aerosols in precipitation and cloud formation. The biggest uncertainty in climate change has to do with aerosols," Schoeberl says. "In short, aerosols are a huge lever and we don't have any idea of their impact on the Earth system."

For example, aerosols — minute particles that are suspended in the atmosphere — can both reflect and absorb solar radiation, either warming or cooling the planet. They interact with clouds, possibly altering precipitation patterns that contribute to floods and drought. They also affect ocean ecosystems. Desert dust provides iron, a key nutrient for phytoplankton, the base of the ocean food chain. Another related question involves the role of the oceans as a sink for carbon dioxide, a major greenhouse gas. The question that ACE could answer is whether changes in the ocean ecosystem are altering its ability to absorb carbon dioxide.

"Current satellite missions are adding to our knowledge," Schoeberl says. "But even the Terra and A-Train sensors don't make the measurements that will allow us to fully answer many fundamental questions."

Reinvigorating Earth-Observing Assets

While Schoeberl and Connerton believe that ACE gets to the heart of today's climate change debate, the mission currently is not ranked in the first group of the Academy's recommended investigations. The Academy suggested that NASA first begin planning ICESat-II (Ice, Cloud, and land Elevation Satellite), CLARREO (Climate Absolute Radiance and Refractivity Observatory), SMAP (Soil Moisture Active Passive), and DESDynI (Deformation, Ecosystem Structure and Dynamics of Ice). "Many were already on the books. Even with the Academy's proposed budget for Earth science, we can't do everything at once," Connerton says. ACE and four others would follow in the 2013-2016 timeframe, and an additional six would come online between 2016-2020.

The important thing now, Schoeberl says, is reinvigorating NASA's Earth-observing assets. "At the very least, we need to continue viewing Earth's important systems well into the next decade with the capabilities that we have now to identify climatically significant trends and other changes." ◆

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Ticket to Ride

Campaign Demonstrates Feasibility of SIRICE

David Starr, a Goddard atmospheric scientist, traveled to Costa Rica last summer to collect ice-cloud data in a campaign funded by the Center's Internal Research and Development program. He successfully demonstrated the viability of his instrument concept.

Although few experts dispute the rationale for flying a space-borne experiment that would specifically measure the amount of ice in the atmosphere, such an investigation has yet to secure a ticket to ride.

If Goddard scientist Mark Schoeberl gets his way, however, the so-called Submillimeter and InfraRed Ice Cloud Experiment (SIRICE) will find a berth on the proposed Aerosol-Cloud-Ecosystems (ACE) mission, which the National Academy of Sciences recommended in its first-ever decadal survey on future Earth-observing missions.

That's good news to atmospheric scientist David Starr, who has spent the last 4 years working with the University of Wisconsin, the University of Colorado, and the Jet Propulsion Laboratory honing a dual-radiometer, moderate-resolution, wide-swath measurement technique that would accurately assess on a daily basis the global distribution of atmospheric ice.

Knowing these values would help scientists to better describe the linkage between the hydrologic and energy cycles in the climate system. Ice clouds are ultimately a product of precipitating cloud systems and dramatically affect the Earth's emission of infrared energy into space and its reflection and absorption of the sun's energy over broad areas. To this day, the amount of atmospheric ice on a global scale remains highly uncertain, Starr says.

The novel SIRICE instrument concept was spawned from the Conical Scanning Submillimeter-wave Imaging Radiometer (CoSSIR), a Goddard-developed airborne ice-measurement instrument. During a field campaign from Costa Rica during the summer, Starr's team used CoSSIR to collect its first observations of ice clouds at 874 GHz, a frequency uniquely sensitive to ice clouds high in the tropical troposphere. It also gathered dual-polarization measurements at 643 GHz, a frequency sensitive to the shape of the ice crystals.

Pleased with the results, Starr says the campaign, funded by the Internal Research and Development program, demonstrated the value of these measurements and represented a major step in demonstrating the feasibility of the instrument and ultimately building community support.

"In the 2020 timeframe, a submillimeter radiometer should become an operational satellite instrument," Starr says. "I want to see NASA do this first. We are ready. What we need is a high-level endorsement of submillimeter measurements in the ACE mission." ◆

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Instrument Shows Versatility in Ice Studies

R&D-Developed Lidar Flies Over Greenland

An instrument that has proven its worth many times over gathering topographical and vegetation data, has accomplished something that no one ever expected it to do: it has measured the rapidly thinning ice sheets over Greenland during an experiment aimed at proving the instrument's viability for all types of climate change studies.

This image of the rough and highly complex ice sheets at Jacobshavn Glacier in Greenland was taken from the window of a P3 aircraft during a campaign to gather precise data on whether the ice sheets were moving up or down.

"We're processing the Greenland data now and it will be ready for release very soon," says Principal Investigator Bryan Blair, who developed the Laser Vegetation Imaging Sensor (LVIS, which is pronounced Elvis) using Goddard R&D funds. "We wanted to see what this instrument, originally optimized for vegetation science, could do for ice science. Now that we have collected the data, we will let the scientists decide."

In recent years, the Greenland ice sheets have captured the attention of scientists worldwide because they are melting at increasingly rapid rates — a phenomenon that could raise global sea levels and contribute to flooding along coastal regions.

Early last year, the National Academy of Sciences released its decadal survey that recommends a variety of space-based missions, which would help scientists better understand the natural and human-induced changes to Earth's land surface, biosphere, atmosphere, and oceans. Some of those missions specifically recommend next-generation investigations of the polar ice sheets and vegetation.

What LVIS Can Do for Ice

The instrument, which can mount into any aircraft that accommodates a standard aerial camera, is a scanning laser altimeter or lidar that sends a laser beam toward a target and measures the time it takes for the signal to return. Since its development nearly 10 years ago, the instrument has become a mainstay for various government agencies and universities requiring information about Earth's topography, the structure of tree canopies, biomass, and surface roughness.

Unlike other lidars, however, LVIS also uses the so-called waveform-based measurement technique that analyzes the shape of the returned pulse, not just the time it took for it to return. The waveform reveals the distribution of surfaces above the terrain, making it especially useful for measuring extremely rough terrain, such as ice sheets that are moving very fast or breaking up.

For the Greenland experiment this past September, Blair deployed his instrument on NASA's P3 aircraft and flew over areas measured by NASA's ICESat (Ice, Cloud, and land Elevation Satellite), a Goddard-developed laser altimeter mission. LVIS collected about 5,000 square kilometers or 2,000 square miles of data using 20-meter (about 66 feet) diameter footprints. The goal was to provide highly precise data on whether the ice sheets were moving up or down; in other words, whether they were melting. "We hope the data can help scientists better understand and evaluate the ICESat data," Blair says.

Just as important, he also wanted to show that the technique was a viable contender for other types of climate change investigations, not just those addressing vegetation. "A lot of people think this is only a vegetation lidar, but this high-quality data set over the ice will expand LVIS's application base."

Space Application Remains the Goal

Ultimately, Blair hopes to see his swath-mapping laser altimeter fly in space. "Right now, LVIS flies at 10 kilometers (more than 6 miles) above the surface. All other airborne lidars fly at 1 kilometer (about a half mile) or lower. Due to the way the laser reflection weakens with distance, 10 kilometers is one hundred times harder to achieve than 1 kilometer. Going to an orbital altitude of 400 to 600 kilometers (250-375 miles) is even harder, but LVIS has a good lead over other sensors."

"Everything we do in terms of technology development and science demonstrations are aimed at getting LVIS into space," Blair says. ◆

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Multi-Year Research Effort Leads to Spring Demonstration Flight

Principal Investigator to Test New Radar Technology

Two years of investment in new radar technologies could pay big dividends for the Goddard Space Flight Center.

The proof will come this spring when Principal Investigator Rafael Rincon demonstrates his Digital Beamforming Synthetic Aperture Radar (DBSAR) onboard a P3 aircraft to obtain real-time, high-resolution topographical images over wide areas of the Delmarva Peninsula.

Should Rincon's technology succeed, he says the capability will further expand the Center's expertise in radar technology and help it to compete more effectively for future Earth science and planetary missions, particularly those calling for measurements of surface water, polar ice sheets, snow thickness, surface topography, land-cover usage, and biomass.

"The technology is an important step for us and offers a significant advantage over conventional synthetic aperture radar," Rincon says. More traditional SAR systems gather data along a narrow swath. They will image larger areas only if the system steers the antenna beam to cover more than one swath, but the trade-off is degraded resolution.

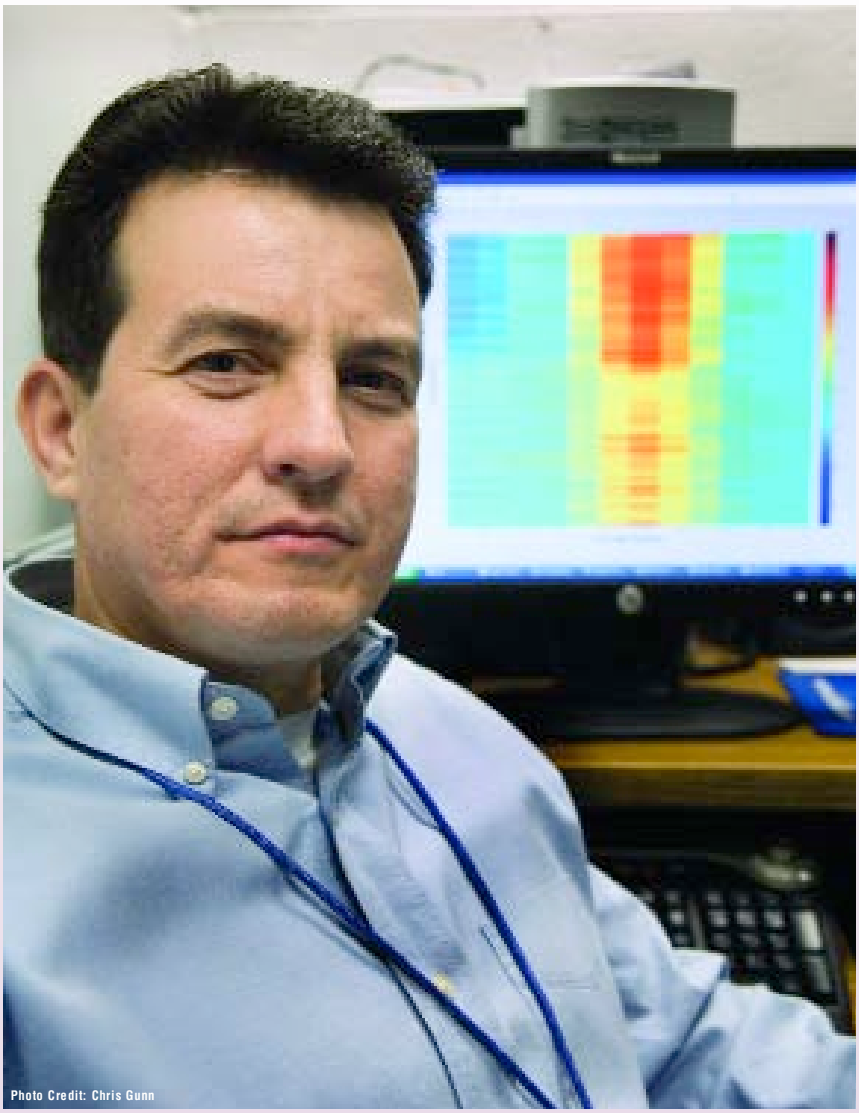

Photo Credit: Chris Gunn

Combination of Two IRAD-Funded Technologies

Rincon's technology overcomes these challenges by combining the L-band imaging radar that Goddard principal investigators developed under a previous Internal Research and Development (IRAD) award, along with a multi-channel, reconfigurable processor, also developed with IRAD funding. By leveraging the two, Rincon will be able to simultaneously synthesize and process multiple radar beams and produce imagery in real time. The end result, he says, is fine spatial resolution over larger areas without moving parts.

"We saw an opportunity to implement these new techniques," Rincon says. "The success really lies in the processing. This is the path that radar is taking. We're trying to move many of the radar functions onto the processor, which will reduce the size and mass of these systems."

Now at a technology readiness level of about a four, Rincon says the ultimate goal is building a system that can fly in space to benefit many Earth and planetary science applications requiring fine resolution and large coverage areas. With the demonstration this spring, he hopes to prove the system and eventually fly science campaigns, including an ecosystem-structure investigation over eastern North American and the central-American tropics, or as part of an ice-dynamics study over Antarctica. ◆

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Vision to Create 'Fire Channel' Takes Step Forward

Witch Fire in San Diego Provided Proving Ground

When the fires begin to burn next year — as they did during the Witch Fire in Southern California in late October — Goddard technologist Dan Mandl and Earth Observing-1 (EO-1) scientist Steve Ungar say they'll be ready to deliver near real-time satellite imagery to firefighters and public health officials who need to battle the blaze and keep residents from harm's way.

The ultimate goal, say the pair, is to create a modular sensor-web architecture that would integrate space and land assets and allow users to task these sensors using the Internet, ultimately making up-to-the minute imagery accessible either on the Web or on television in the form of a "fire channel," much like the Weather Channel.

During the Witch Fire, they realized at least some of their goals.

Working with Eric Frost, head of the Visualization Lab at San Diego State University and an associate of the San Diego Emergency Operations Center, they used the Moderate Resolution Imaging Spectroradiometer on the Terra and Aqua satellites to locate in near real time active fires in specific areas of interest. The selected hot spots triggered, either semi-manually or automatically, follow-up images by EO-1. These images then were used to select flight paths for an instrument-equipped unmanned aerial vehicle managed by the Ames Research Center. Frost described the resulting data as "spectacular."

Ultimately, Mandl would like to see the data used to autonomously make maps for broadcast on a television or Internet-based fire channel. "Using our web of sensors, we took some preliminary steps in that direction," he said.

During the California fires, a San Diego television station created a Web site and aired a map to show viewers the locations of the fires. The Web site received 1 million hits during the first day of operations.

It also would allow public health officials and others to more effectively evacuate people who were at risk. The need became evident when residents of Tijuana feared that the fires would spread to their city. Armed with the NASA data, however, Frost visited Tijuana, and together with the city's mayor, assured the people that the fires posed no threat and that evacuation was unnecessary.

The Advanced Land Imager onboard NASA's EO-1 satellite saw through the smoke to capture these images of actively burning areas during Southern California's Witch Fire in late October.

"NASA scored incredibly in the media because of tactical response and by providing real things that really helped and worked," Frost said. "Information from NASA satellites provided over the Internet and media had a massive positive effect." ◆

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Goddard Tech Trends

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