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Earth Sciences Subcommittee

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NASA Headquarters
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MEETING MINUTES

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Steve Running, Chair

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Lucia S. Tsaoussi, Executive Secretary

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Opening Remarks

Dr. Lucia Tsaoussi, Executive Secretary of the Earth Science Subcommittee (ESS) of the NASA Advisory Committee (NAC) began the meeting by noting the presence of several new members. This was also Dr. Steve Running's first meeting as ESS chair. The meeting was open to the public, with a public comment period scheduled for the end of the first day. The Subcommittee members were to receive Ethics Training in a closed session on the second day of the meeting.

Earth Science Division Update

Dr. Michael Freilich, Director of NASA's Earth Science Division (ESD), provided an update on Division activities, starting with an overview and leading into more detailed discussions of three areas: sustained land imaging, ongoing measurements that have shifted to ESD, and education/public outreach (EPO).

The President's Fiscal Year 2015 (FY15) budget request is flat, about $1.8 billion, which is neither good nor bad but does provide stability. Congress has generally appropriated what the President requests. Therefore, ESD will not have to change its plans significantly to accommodate budget fluctuations.

The Division strategy is to balance funding on flight programs and on driving forward the science. The latter enables use of the measurements obtained from the space-borne hardware. ESD has about a 60/40 flight/non-flight balance, which is not readily apparent in the budget but has been the pattern for the past 4 or 5 years.

ESD is organized into four major areas: flight, research and analysis (R&A), applied science, and technology, all of which feed into each other in various ways. Dr. Freilich cautioned that balance in the program is not the same as equal funding. Flight receives 61 percent of the budget, with R&A receiving 34 percent, applied science 2 percent, and technology 3 percent. There is pressure from all directions to change this, but it has been stable and it works in terms of the overall portfolio. Dr. Freilich promised to provide more detail later in the meeting.

Missions

Dr. Freilich showed a graphic representation of the current and future ESD research mission flight constellation. There are 17 research missions flying at the moment, and these form the backbone of the nation's research observing fleet. Some are in close constellation with each other, creating virtual observatories. The missions span a range of types, from large multi-instrument missions to small, focused instruments. They span a range of measurements as well.

JASON-1 has completed its mission and has been shut down. Its transmitter failed, though the satellite itself was performing. When the French turned it off, it started to drift. The Active Cavity Radiometer Irradiance Monitor Satellite (ACRIMSAT) has not been heard from for months, aside from a few seconds, and ESD will soon consider it terminated. The Total solar irradiance Calibration Transfer Experiment (TCTE) has taken on some of the work previously done by the Solar Radiation and Climate Experiment (SORCE) satellite. Many missions are continuing to operate beyond their lifetimes. In odd-numbered years, ESD conducts a senior review of operating missions that are beyond their designed lifetime.

The Division has a good number of missions under development, including five that will launch in 2014. Three of these Earth-observing (EO) missions were developed by ESD, and two are instruments developed for and in conjunction with the International Space Station (ISS). There will be nine more ESD EO launches before 2022.

The Global Precipitation Measurement (GPM) satellite was launched successfully in February, 2014. The first Orbiting Carbon Observatory (OCO)-2 had a launch vehicle failure in 2009, but will launch again on July 1st from a Delta II. In summer and fall of 2014, two instruments for ISS will launch; they are RapidSCAT and the Cloud-Aerosol Transport System (CATS). Both were funded by the ISS program. ESD will take on data analysis once they are in orbit. The Soil Moisture Active Passive (SMAP) mission will launch in November on a Delta II. After that, ESD will launch an average of two new missions per year for the next decade.

Dr. Freilich next presented the ESD orbital flight portfolio, in which the vast majority of flights are on schedule. The Stratospheric Aerosol and Gas Experiment (SAGE) and the Ice, Clouds, and Land Elevation Satellite 2 (ICESat-2) mission have had development issues. The Climate Absolute Radiance and Refractivity Observatory (CLARREO) mission is not going to launch as planned, though portions could go to ISS. OCO-3 was postponed by the President's budget request, as it did not fit into the funding deal made with Congress. However, it is NASA's second priority for return among those items that were cut or postponed. The barrier for reinstatement is low, and it will go to ISS using spare parts in segments.

ESD is actively working with ISS to build, fly, and insert instruments. While these scenarios might not be perfect, the cost/benefit ratio is very good, with the costs to ESD being extremely low. The payoff is large, and the partnership helps mesh science exploration with human space exploration. The signed agreement to run ISS is through 2020, but negotiations are taking place to extend it through 2024.

Venture Class missions

The Venture Class missions are science-driven, led by Principal Investigators (PIs), competitively selected, cost- and schedule-constrained, and regularly solicited, reflecting a high priority of the Decadal Survey (DS). The objective is to be nimble in addressing evolving science and new implementation approaches that may differ from the systematic missions. Venture Class has three strands: suborbital; small-sat/missions; and instruments. The cost and schedule caps are key and cannot be pushed without termination. ESD has made the first set of selections, which are well into implementation, and the next round of selections is on schedule. Venture Class accounts for 12 percent of the ESD budget.

Dr. Frelich provided more detail about the three strands:

- EV-suborbital (EV-1) is solicited every 4 years. All five investigations selected in the first round are well into sustained field campaigns.
- EV-M (EV-2) is also solicited every 4 years, off-set from EV-1 by 2 years. These are small satellites. The Cyclone Global Navigation Satellite System (CYGNSS) had a successful Key Decision Point-C (KDP-C) in February 2014 and is going extremely well. It involves eight small satellites that fly in formation to measure extreme weather events. The FY15 budget includes funds for the next EV-2 solicitation.
- EV-I (Instrument) is solicited every 18 months. The Tropospheric Emissions: Monitoring of Pollution (TEMPO) instrument had a successful KDP-B in April. EV-I is well along in the selection process for the submissions from the second solicitation.

Cubesats can fit into EV-M or EV-I. There is no prohibition on applying for renewal, but this program specifically seeks new proposals. This program does everything the DS advised, and ESD is trying to make it part of the Division culture. The Venture Class funds are not merged with funding for the rest of the program.

Science

There is much great science being done out of ESD. In an example involving forest coverage, Dr. Freilich explained that the objective is to move forward the science, but the instruments and measurements need not all come from NASA. The forest cover change measurements have resulted from foundational work that was done at the NASA Ames Research Center, using great quantities of Landsat data and algorithms.

GPM is being run in conjunction with the Japanese Space Agency (JAXA), which launched the satellite from an H2A launch vehicle and contributed a couple of instruments. GPM provides highly accurate measurements of rain rates and can use geophysical information from other missions to provide data on precipitation. This is essential in order to close the hydrological cycle. The satellite can also measure light rain and snow over large areas more frequently than was previously possible. The commissioning period was almost complete at the time of the meeting, and the full operational science mission was about to begin. Data will go to early release because it looks so good.

Airborne science aircraft calibrate space measurements or measure what is beyond the capacity of spacecraft to detect. The DS suggested an increase in flight hours, which ESD has done by nearly a factor of three, with almost 3,000 hours annually at this point. Dr. Freilich said that he does not believe the program can grow any further. To provide an example, he presented a lengthy list of the program's accomplishments during March and April.

There were many Studies of Emissions, Atmospheric Composition, Clouds, and Climate Coupling by Regional Surveys (SEAC4RS) flights in late summer of 2013. The program is now run from the United States. It successfully sampled fires, monsoons, convection, storms, pollution plumes, and gas phase chemistry. The airborne program had a record day on September 4, 2013, with seven different NASA-deployed aircraft flying at once. IceBridge is being used to bridge between ICESat-1 and ICESat-2 in continuing the climate data record. The program connects with classrooms around the world, enabling students to talk with scientists.

The Applied Sciences Program enables identification of applications early in a satellite mission lifecycle, while integrating user needs into satellite mission planning and throughout the mission lifecycle. The program helps builds U.S. and developing countries' capacity to use Earth science data in decision-making. The focus is on health, water, disasters, ecosystems, and comparable areas. One development has been a partnership with the California Department of Water Resources (CDWR) for remote sensing for drought monitoring. This effort studies levies and canals in addition to water and snow sources. The Moderate Resolution Imaging Spectroradiometer (MODIS) feeds data used for a monthly global crop report, and takes standardized crop health assessments.

An Applied Sciences Program early adopters program brings in potential end users early in the mission design cycle to help familiarize them with the data sets and help the mission understand their needs. SMAP was the key initial focus for this, with about 35 early adopters. Otherwise, it may take years for users to engage with a research mission. Japan has done this quite successfully.

Earth Science Technology Office (ESTO)
ESTO is a targeted, science-driven, competed, and actively managed technology program. It has four strands: Instrument Incubator Program (IIP); Advanced Component Technologies (ACT); Advanced Information Systems Technology (AIST); and, In-Space Validation of Earth Science Technologies (InVEST). ESD is the first division in NASA's Science Mission Directorate (SMD) to explore the use of cubesats for validation. While it is not possible to determine if this results in cost savings, it is possible to ask if there are areas where ESD is loath to fly future missions due to lack of technology. For example, the area of active laser remote sensing is not quite fully developed, which probably holds back approval of some of those missions.

Dr. Mahta Moghaddam observed that the funding seems small for a lot of the instrument prototypes that are being developed. Dr. Freilich suggested that it might be time to have another full discussion of ESTO, especially given that much of the ESS membership has turned over since the last discussion. He challenged all ESS members to think in terms of what they would cut if they shifted funds in order to increase support for a particular item. He added that ESD has been conservative with Venture Class to show that it can succeed, and may be more flexible in the future.

Two cubesats were launched in December, 2013, for the second flight of the Michigan Multipurpose Minisatellite (MCubed-2), which has a camera and processor. This flight is validating an on-board data processing technology in space and doing imaging.

Climate Action Plan (CAP) and Climate Data Initiative (CDI)
The CAP is an Administration priority; the CDI is a data-intense effort that will leverage Federal climate-relevant data beyond the government. NASA was asked to lead CDI, which involves populating an online catalogue of climate data, creating innovation challenges and incentives, engaging stakeholders, and developing commitments from non-government players. Many of these activities overlap and intersect. CDI has seven societal benefit themes, each with a lead agency. The meta-data are gotten out in well-defined form to a climate data website. NASA received $6 million in FY14 to support CDI and the Big Earth Data Initiative (BEDI). CDI and BEDI are related, with the former having a near-term focus and BEDI looking more long-term. CDI includes a targeted effort related to climate resilience. BEDI standardizes and optimizes the management and delivery of Federal Earth observation data.

Recommendation documents
ESD receives guidance from key guiding recommendation documents, particularly the 2007 DS, "Earth Science and Applications from Space," the 2010 NASA response to the climate plan, and the 2012 National Research Council (NRC) midterm report on ESD response to the 2007 DS. The NRC recommendations are not the last word on what NASA should do in Earth science; the Administration and Congress also have input. The 2010 report addressed having an executable plan, while the midterm report was highly complimentary of ESD, given the Division's resources.

In the next DS, it is important that NRC focus on an executable Earth science program. NRC must consider that the Administration and Congress have input, and ESD will need to implement sustained measurements to support the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Geological Survey (USGS). The ESD budget will not increase substantially and may even decrease. Mission costs, schedules, and so on can only be pre-defined or controlled in competitively selected and constrained programs like Venture Class, not in directed, systematic missions. Directed missions to NASA centers are essential to the Agency, however. The named-mission backlog from the first DS is substantial. Decadal surveys in general identify the missions that will really be done in the next decade and ratify the ones that are being done in the current decade. The most useful inputs from the DS are relative to balance and content, and not so much individual missions. The DS organized community input and themes. The next DS needs to reflect realities, however, or it will not be as useful.

Useful inputs from the DS include the recommended target budgetary balance between flight and non-flight programs. In the non-flight portion of the program, the DS can recommend the substance, not the percentage, of what should be done. In the flight portion of the program, the balance between competed and directed missions should be addressed. Dr. Freilich would like to see the following questions addressed as well:

- Are there missions ESD should not try?
- What is the maximum acceptable cost?
- Should there be other Venture Class-like programs with different caps?

- What about flight mission architecture and approach?
- Where should the engineering investments originate?

The DS should provide decision principles for balancing new measurements and time series extensions of existing data sets. NRC should accept budget limitations, including those of international missions, and should revisit the priorities of the named missions from the first DS. NRC should also determine if ESD should change the scopes of the R&A, applied science, and technology programs.

Discussion
Dr. Anna Nolin said that one of the DS recommendations was to have NASA engineers and PIs discuss some of the issues for moving forward. The intent was to facilitate the breakdown of stovepipes. Dr. Freilich replied that stovepiping is not much of a problem, as there is much crossover among the program offices. In terms of estimating costs, that has improved. ESD has brought a level of rigor to the process. With very few exceptions, when a mission is confirmed, it is backed by good internal statistical analyses and has had significant oversight and validation, often with external review. This is not perfect, and it is difficult, with ICESat-2 being a prominent example. Still, ESD has many launches occurring on time and under budget. The Division is attaining efficiencies that send funds back to ESD, which are used to solve the occasional problem. Projects go into KDP-C at 70 percent confidence, and it works.

International partnerships help extend ESD's reach. Space agencies like to have joint missions, but there are other ways to work internationally, like the A-train, which flies in formation. The European Sentinel System provides opportunities for additions. ESD meets regularly with the European Space Agency (ESA) to explore options. NASA is starting to realize the value of SMD's work, while there is good cooperation among the divisions within the Directorate.

Sustained Land Imaging
Dr. Freilich next discussed ESD's sustained land imaging program. Landsat 8 launched in late winter of 2013 and is exceeding specifications. The Obama Administration values sustained land imaging, and the President's budget for FY14 featured a new activity to design such a system, with three basic attributes:

- Sustainable – realistic budgets over the long haul;
- Continuity – continue the long-term Landsat data record with usable products that define the utility of the data record; and,
- Reliability – functional redundancy, so there is no overreliance on a particular instrument, though not everything has to come from the U.S. government.

NASA's role is to lead the system architecture, and to design, implement, launch, and commission on-orbit the USGS spaceborne segment. The USGS role is representing the user communities, while also engaging in operations and data activities. Cost is a constraint, at an average of $120 million per year for NASA over the system lifetime. NASA is to examine international and private sector partnerships, with the results due in August, 2014. The FY14 and FY15 budget requests included consideration of standalone new instruments and satellites. Congress is concerned about Landsat 9, however, and the international partnerships. Congress therefore asked for a plan with a $650 million total mission cost, substantially below what the Administration requested.

NASA and USGS established a land imaging architecture study team (AST). There has been a community workshop, and the AST is doing lots of analysis and creating options. Cost is not inconsequential to sustainability. AST will look rigorously and quickly at a broad trade space. The goal is to balance cost, continuity, risk, and capabilities. The AST members have diverse backgrounds, and not all are in the government. The study schedule includes three cycles and runs from August, 2013, through August,

2014. AST is keeping the President and the Office of Science and Technology Policy (OST) in the loop, while also working closely with USGS.

USGS has the closest contact with Landsat users and has identified user needs based on targeted elicitations of land imaging user communities. AST will try to distinguish between the prior use, needs, and desires of those communities, and also develop a systems requirements and user analysis document. Dr. Freilich gave some examples of requirements that have evolved from user input. For example, Landsat cannot go lower than 30-meter resolution without losing large segments of the user community. Thermal infrared is another feature of significant interest to users and other stakeholders. This was not in the original plan, but AST has now added it. The real issue is coverage of the system and how rapidly every point is sampled. ESD is interested in the total system more than in the individual satellites.

From a chart on key system performance aspects, Dr. Freilich zeroed in on the mission's ability to image each point on the globe every 16 days, preferably every 8 days. This is essential. AST has defined a huge range of architectures encompassing instruments, spacecraft platforms, risk, launch vehicles, potential technology infusion, partnership, and business models. There must be a plan for what to do if an individual instrument fails, for example.

While AST has identified viable architectures within the constraints of the study, none are perfect. Another Landsat 8 type has cost issues that could bleed into schedule issues. Thermal infrared-only satellites rely on foreign systems. A new and unproven combined scanning instrument has great promise with lowered costs but with higher development risks. Architectures that disaggregate have the problems of budget issues, though small satellites with reduced launch vehicle costs may help. The bottom line is that NASA and USGS may have to consider leaving their historic comfort zone.

This is added scope to the ESD portfolio. It is not in the DS, but it is directed from a high level. The nation needs something like this. ESS understands the high-level pressures on the ESD budget, which may be a space for weighing in at some point. However, it would be helpful to have the Subcommittee's input after the report is issued in August. Any teleconference would be subject to Federal Advisory Committee Act (FACA) rules. The report does not have to go to Congress.

Discussion
Dr. Nolin asked why the Landsat costs are so high, when there have been so many. Dr. Freilich explained that cost efficiencies are only possible when there is a block buy followed by a sequential build, and that does not happen with Landsat. In addition, design of one unique part may necessitate redesign of other parts, and design teams have dispersed. There are also upfront costs on block buys.

Dr. Christian Kummerow asked if the $120 million costs are part of a pattern that will erode the ESD budget. Dr. Freilich replied that the simple answer is "yes," but the Division received a budget increase for most of it. The positive side is that ESD has performed, delivering a strong program, which is why the Division is asked to do some of these long-term projects.

Noting that USGS is responsible for all downlink, data processing, and archives, Dr. Running asked if that would be part of this report. Dr. Frelich said that it would be. Changes in architecture from the Landsat 8 approach impose some costs on the USGS side. USGS does not have a corresponding budget, and the AST decided to inflate the dollar amounts. Any reprocessing of the entire archive would be up to USGS, which needs to review continuity in terms of the user community.

<u>EPO Approach</u>

The final decisions on how to manage EPO have yet to be made at the higher levels, including SMD and Congress. NASA policy directives 1380.1 and 1388.1 define education and communications. "Education" covers activities designed to enhance the science, technology, engineering, and mathematics (STEM) content area learning using NASA's unique capabilities. "Communications" involves conveying to the public and other stakeholders what NASA has done and the impact of its activities on their lives. This is broad, and covers media and public engagement.

The FY14 budget focus is on efficiency. The President asked the various science agencies to rethink education. However, at NASA, education was always integrated with public outreach, so there is an ongoing effort to disentangle the two. An SMD directive had had 1 percent of major mission costs set aside for EPO; that is no longer the case. ESD is looking at the substance of what the projects are doing in education and communication, and determining where to go with that. The single exception is the Global Learning and Observations to Benefit the Environment (GLOBE) program, which had its funding sent to the NASA education office. The appropriators in Congress maintained EPO funding within SMD, and asked that each division have EPO funds rather than allocating the funds by project.

There are ongoing programs that people are concerned about, but ESD attempted to get ahead of this to the extent possible. The approach is to provide stability and direction to the extent possible. Through FY15, ESD will continue funding direct education programs such as GLOBE, and support EPO in individual flight missions as justified. The Division will also support synergistic activities from multiple missions, and will support cross-directorate EPO and communications.

SMD is trying to navigate this, and is suggesting that future budget requests should include education activities. Dr. Freilich was unsure of the motivation for putting EPO on the chopping block, but suspected that the Administration was trying to maintain sustainability in this area by turning to agencies with long histories and expertise in EPO. NASA is unique in maintaining public interest through programs that go to Mars, look at Earth from space, and so on, tying big science to people's lives.

GLOBE is international, provides students with hands-on activities, and is essential to building on the NASA brand. In 20 years of GLOBE, about 66,000 teachers have been active for at least a year, in turn affecting their students. The program has taken more than 90 million Earth system measurements, and has done science validation. GLOBE supports U.S. diplomatic efforts through an office at the State Department. About 75 developing countries have had programs for 10 years, and 14 have had 20 years of programs. There are 109 international country partners.

In other communications activities, NASA recognized early on that this would be a big year for Earth science, and has used the five mission launches to bring in people. There was a "global selfie" day on Earth Day, with an amazing level of participation. NASA has also been involved in communicating key science results, like the west Antarctic ice sheet melting. NASA is unique in being both a space agency and a science agency. The other international space agencies are very different in that regard.

Comments from the SMD Associate Administrator

Dr. John Grunsfeld, SMD Associate Administrator (AA), stopped by the meeting for a brief discussion with ESS members. He said that SMD not only pays U.S. investigators to do science, it also pays scientists and engineers to support the observations. He thanked the Subcommittee members for supporting ESD. Earth science is both interesting and important. As we move into 2020s, the kinds of things being discussed at this meeting will be mainstream, and SMD will be looking at adaptation issues. ESS is helping with future decision-making, and he appreciated their help.

ESD Discussion

After lunch, Dr. Tsaoussi explained that the letter that ESS would develop the next day could include observations, findings, and recommendations. The findings and observations are timely, so the letter had to be written and provided to ESD soon in order to be relevant. The findings and recommendations are developed as a group. Dr. Running asked the Subcommittee members to think about topics they wished to include in the letter. The letter is addressed to the NAC Science Committee, which reports to the NAC. However, the letter also goes to the Division and is part of the public record.

Dr. Efi Foufoula-Georgiou asked if the $6 million for CDI activity might be used for existing data at NASA. Dr. Tsaoussi explained that that funding is actually interagency and designated for a specific purpose. Dr. Running added that the upcoming climate sensor discussion might provide more of a basis for revisiting this question and discussing data continuity in that context.

Dr. Nolin said that she was not happy with Dr. Freilich's response to her question regarding the management structure committee recommended by the DS. The recommendation was to have a more integrated discussion of the science. The update ESS received was more about mission launches and not a big-picture discussion of the science. Dr. Herman Shugart , Jr., noted the overarching issue of flat funding for 4 or 5 years, which would make it understandable that ESD would be happy to have five missions in a short time. However, he was concerned about where the innovation is originating. Venture Class might be part of it, but that is small. The climate deniers are losing steam, so this may be a time of opportunity to voice what Earth scientists need to know.

Dr. Moghaddam noted an apparent mismatch of scale between technology development and flight. She wondered how to best bring the former into more relevance with the flight program. Dr. Thomas Herring wondered how much technology development is done within the flight missions themselves, and if there might be a need for more coordination.

Ms. Kathleen Green listed four topics she wanted the letter to address:

1. Compliments to ESD on its accomplishments, including the launches.
2. Sustained land imaging.
3. Big items from the DS, where that is going, and what to recommend.
4. Early adopter program.

Dr. Running added that this was the Subcommittee's best chance to influence the next DS. Dr. Roland Burgmann said that ESS must also address the budget for directed programs. The issue of smaller, more flexible missions must have come up many times before, but he wondered whether flagship missions might be better for innovation. Dr. Nolin advised reading the mid-term NRC document to determine the strategies for smaller missions.

Dr. M. Patrick McCormick doubted that the next DS would include the same unrealistic numbers as the original. He noted that when a directed program is given to a NASA center, that center pours people and money into it. The PI-directed studies are very cost-contained. To be selected for EV-I as a PI-led mission, proposers must provide substantial proof for technology readiness level 6 (TRL6). If the mission goes over cost, it is kicked out. The Aeronomy of Ice in the Mesosphere (AIM) was a Heliophysics Division (HPD) Discovery program that underwent 52 reviews because the program was risk-averse. Those who propose new technology will never get selected or win a mission. That culture has to change.

Dr. James Marshall Shepherd said that the process by which ideas come into the mix is still unclear. The DS does not mention it, even for critical technology. Dr. Running said that this might be something to

comment on in preparation for the upcoming DS; it might warrant a recommendation. Dr. McCormick observed that the DS would state that ESD should do a given mission, but would not provide any of the criteria or process. It is important to define the measurements needed, not just state the mission. Dr. Burgmann said that the NRC panel had a hard time reconciling the disparate interests of the various groups from different disciplines.

Dr. Richard Rood felt that ESS was not hearing much about modeling, which does not seem to emerge as a strategic interest. Dr. Tsaoussi said that almost three years ago, there had been a two-day modeling meeting, but few recommendations came out of it. There would be more discussion of modeling the following day. Dr. Foufoula-Georgiou said that she is part of a group coming up with ideas for the next DS. One is to give more emphasis to direction and science needs rather than missions. The second is about integration of data and modeling, and how it goes back to the community for research.

Dr. Greg Carmichael said that while there were some positive developments within ESD, it was not clear how the Division would adapt to changes in scope. A strategy to deal with opportunities would be helpful. Dr. Kummerow said he would like to know more about both the process of building the risk model and the steps to get to a mission. Dr. McCormick thought the Venture Class program had some good elements, and he liked that it offers opportunities to PIs and smaller companies.

Dr. Nolin said that with the airborne program, the science can respond nimbly, but when something is in space, it is up there. The airborne science program has regular meetings with its PIs, which not all programs do. The Venture Class projects are great, but having something else is of tremendous value. Dr. Jack Kaye of ESD noted that EV-Ms allow for more risk, but with a fairly mature payload. With airborne, it is easy to focus on platforms, but the ability to integrate them with sensors and people matters, too. Although there is some technology development with built-in science requirements, there is not a lot of this in the R&A program. It is hard to get much funding unless the effort is to evolve something that already exists.

Climate Sensors and Products

Dr. Steve Volz of ESD spoke about Radiation, Ozone, Atmospheric Measurements (ROAM). He began by showing the President's FY15 budget justification, in which responsibility for the following three measurements was transferred to ESD from NOAA:

- Radiation Budget Instrument (RBI) on Joint Polar Satellite System 2 (JPSS-2);
- Ozone Mapper and Profiler Suite (OMPS) Limb on JPSS-2; and
- Total and Spectral Solar Irradiance Sensor 2 (TSIS-2) on a platform yet to be determined.

The budget is available to secure a single extension of each of these for one generation, into the early 2020s. Some funding was sent to ESD for ROAM, but the rest came from reallocation. The Earth radiation budget has a long history. Because there are no Clouds and the Earth's Radiant Energy System (CERES) instrument parts left, the program is building a new instrument. The intent is to continue the OMPS-Limb measurements in ozone profiles. The solar irradiance measurements that started in the 1980s will continue. NASA has supported and will continue data integration, analysis, processing, algorithms, and maintenance for these over the long term.

RBI is planned to launch in November as one of five instruments in the JPSS-2 mission. NASA will deliver the instrument to NOAA and manage data product generation and dissemination, though NOAA will do the operations. NOAA is under pressure to accelerate the launch. There is a good likelihood of overlap between the CERES and RBI flight schedules. There is also a contract in place for OMPS-Limb.

NASA will develop TSIS-2 as a follow-on instrument to the TSIS-1. NOAA is looking at ways to fly TSIS-1. If that succeeds, TSIS-2 may go up in 2017. SORCE is running on minimum battery power. It is providing good data at this point, but there is concern that it will be down again. The Air Force flew a mission for calibration.

Dr. Shepherd asked about the current relationship of NASA and NOAA, and the programs that are moving around. Dr. Volz replied that NOAA has an operational weather function, and these instruments are not weather-related. In addition, they originated at NASA. The two agencies are working closely on this. There are concerns about delays, but there is margin in the schedule.

Discussion

Dr. Herring asked about NASA's level of budgetary risk on this. Dr. Freilich replied that the budget covers one generation for each of the three missions. The estimates are conservative. The various science communities need measurement capabilities to generate both near-term and long-term weather data. However, NOAA focuses on near-term weather prediction and does not use data that comes in late. Dr. Carmichael said that internationally, the line is being blurred regarding the needs of the communities. Ten years from now, the decisions might revert back. The data will be used broadly, and ESS should recommend that. Dr. Nolin asked if NOAA will continue the long-term archive of sea ice data. Dr. Freilich was not aware of a discontinuation, but thought that the question should go directly to NOAA.

Dr. Andrew Dessler asked about the likely future of CLARREO. Dr. Freilich replied that the team has looked at ways of efficiently achieving its goals with CLARREO, which rapidly detects trends in radiation. Approaches under consideration include making instruments smaller, flying them separately, etc. There is no current funding to fly CLARREO with its present cost profile. ESD will ask the next DS panel to look at the mission and its viability as a science priority.

Dr. Joughlin asked for more information about post-launch calibration data. Dr. Freilich explained that ESD is doing all data processing for NASA and NOAA on one of the missions. In addition, the new RBI has some calibration changes to make it more viable as a standalone effort. Dr. Volz added that this still requires overlap, but not to the same extent. The budget assumes that missions last into infinity, which they do not. The budget for all operating missions is about $140 million per year.

Ms. Green asked whether it would be helpful for ESS to craft a recommendation on EPO. Dr. Freilich explained that this issue cuts across all of SMD, and therefore it would be most helpful to talk to other the subcommittees and develop a coordinated strategy. Dr. Running said that there is a NAC meeting scheduled for the end of July. It would help to have a statement he could present at that time. After some discussion of the logistics involved in coordinating with the other subcommittees, it was agreed that Dr. Running would talk to his fellow subcommittee chairs.

Dr. Moghaddam said it looked like education is being cut after FY15. Dr. Freilich agreed that no one should plan on it. The idea had been for education to be pulled up to a higher level at NASA instead of being done at the project level. Dr. Shugart said that it would be hard to argue against a coherent education program, but what exists is working well. Ms. Green disagreed, however, stating that education at NASA is too disparate. Dr. Freilich went on to explain GLOBE funding and infrastructure. The various program elements are dispersed, with NASA and the National Science Foundation (NSF) being the most consistent funders and supporters. Other agencies make more episodic contributions. In 2006-10, the GLOBE implementation office was not spending all of its funds.

Dr. Joughlin suggested that education and public outreach might be not a good combination. Dr. Freilich said that the funding change is for education. The problems and confusion come from the fact that everyone was doing EPO as a unit, and the education portion had to be teased out.

Dr. Foufoula-Georgiou noted the 25th anniversary of the Earth Observer report. Initially, the Earth science focus was on water. The field is now in an era of focus on sustainability. She advised that any recommendation to the DS take into account where the science has been and where it is going.

Dr. Running suggested thinking of whether ESS could make a useful statement regarding ICESat-2 and ISS. ESD has discovered the latter's use for getting sensors up. Half a dozen years ago, it was not even a topic of discussion. Dr. Freilich said that ESD has several instruments currently on or soon to be on the Station. It is in a unique orbit and allows sampling of the diurnal cycle. It drops every day, and it is low, which facilitates some measurements. The Division decided not to let "better" get in the way of "something." Meanwhile, the ISS program is highly motivated to demonstrate science. This could change, but for now it is a win-win situation. ESD does not look to it for flagship missions or key measurements. There is tremendous integration with the ISS office now. As for a finding or recommendation to encourage this, he thought there might be something useful ESS could suggest.

Dr. Freilich reported that he had just received more information with respect to ICESat-2, as the baseline had just been accepted that day. The Atlas instrument ran into every kind of difficulty imaginable. ESD confirmed it in 2012, saw instant degradation, and spent 2013 working on it. It will now receive about $200 million more. The launch date has slipped by about a year from the original plan. The Division will present lessons learned, and Goddard Space Flight Center (GSFC) has made several changes. The management structure has been shifted as well.

None of this is easy. The centers are the technical authorities, but Headquarters management must be rigorous, too. He was not sure what ESS could do now that the decision has been made to go forward. The mission has strong support from SMD and the Agency. There were multiple issues. The team and the instrument differed from ICESat-1. Dr. Volz added that despite this, the perception was that NASA was building something it knew. Instead, the project went with an instrument that it did not know well enough. This shows a need to identify technology risks earlier. Dr. Freilich said that the primary issue occurred with the degradation that began immediately after confirmation.

The science of this mission remains valuable. The Division looked at alternatives. However, once a mission is confirmed, it is extremely hard to back away from it if there are no cost constraints. The analog lasers cannot be built for life sciences and would have been extraordinarily expensive. Some of the other alternatives, like the Global Hawks, are hard to maintain, operate, and fly. A test of the Hawks in Taiwan was disappointing.

Regarding the upcoming OCO-2 launch and Environmental Protection Agency (EPA) carbon regulations, Dr. Freilich explained that NASA provides measurements on which policy can be built, but it is open to everyone. There is a need for extreme caution when it comes to possible involvement in the regulatory aspects of other agencies. The OCO-2 measurements allow scientists to understand the contributions of extended natural sources, and to understand the quantitative elements of forests and southern oceans.

Dr. Shepherd asked about the interaction between program managers and the NASA public affairs people. He thought some of the press releases were over the top, and one of his colleagues found a particular headline to be cringe-inducing. Dr. Kaye said that any press release that goes out is run by the appropriate program manager for feedback, and Dr. Freilich receives them as well. Some are fine, and others are heavily edited. ESD can and does push back. But once something goes out, they cannot control it. It was noted that the headline writer is often different from the person who wrote the text, and ESD has a

communications person embedded in the Division. Ms. Green added that it is not unusual for scientists to be uncomfortable with the media.

Public Comment
A public comment period had been set aside for those not on the Subcommittee or within NASA. However, there were no comments.

Adjourn Day One
The meeting was adjourned for the day at 5:04 p.m.

Thursday, May 29, 2014

Session Overview
Dr. Running opened the meeting. The first item on the agenda was Ethics Training, which was a closed session.

Discussion
After the training session ended and the meeting was opened to the public, Dr. Running introduced Dr. Ming Ying Wei of NASA, who was there to discuss the Agency's EPO strategy and GLOBE.

Dr. Shugart expressed concern about the substantial restructuring of education. Dr. Wei explained that the President's budget proposal meant to consolidate education at three key agencies. That did not appeal to Congress, which did not enact that plan. Everyone in NASA realizes the close tie between the Agency and its science activities. The Smithsonian does not have the infrastructure to run the NASA education grants, for example, and there are other reasons to keep it at the Agency. The appropriation has been reduced, but it has not gone away.

Dr. Shugart stated that no other Federal agency promotes Earth science in a meaningful way like NASA does, and shaking that up would really dilute it. Dr. Wei said that she works with NSF to maintain that situation. NASA is the lead agency for GLOBE. Dr. Foufoula-Georgiou added that there is a difference between integration and centralization. Context is important. Dr. Wei noted that she was not sure how many scientists and engineers are in the Department of Education (DoEd), but NASA tries to coordinate with the Department. The each of the environment-related agencies has a different way of doing things. GLOBE will stay in ESD for the foreseeable future. Dr. Running said that ESS would provide a recommendation on it.

Arctic Science Coordination
Dr. Kaye introduced the topic of NASA's Arctic science coordination by discussing the polar portfolio. Satellite observations for polar and Earth system science address a broad range of science questions using a variety of satellites and sensors. The system instruments fly over each pole 14 to 16 times each day. This positions the United States well to study the Arctic, including through some synthesis-specific projects. In addition, there are many airborne and field campaigns. Topics include ice sheets, sea ice, snow melt, atmosphere, clouds, tides, and ocean biology. International and inter-agency collaborations are integral to the NASA program. NASA's polar work addresses critical questions about sea level rise

stemming from polar melt, the impact on the weather and on Alaska's economy, and the cause of this dramatic change.

NASA has many connections with other agencies on specific projects and programs. The Interagency Arctic Research Policy Committee (IARPC) Research Plan is at the core of these interactions, although there are other strategic documents and implementation documents in play, some of which include the Antarctic. However, the national focus is on the Arctic. In 2015, the United States, through the State Department, will assume the chair of the eight-nation Arctic Council. IARPC is good at understanding that the issues go beyond just ice. The National Arctic Strategies (NAS) has done some important studies, a number of which have been at NASA's request.

The 2013 Inter-Disciplinary Science (IDS) call made selections focusing on two areas: the impacts of Arctic ice change on mid-latitudes, and permafrost. SMAP, which will launch in November, will include an Arctic focus in its global measurements. The ICESat-2 measurement concept and coverage will be a significant advance over its predecessor. ICESat has found that the last 7 years have seen the lowest seven minimum extents ever recorded for Arctic sea ice.

Dr. Kaye also mentioned the CryoSat-2 discoveries regarding sea ice freeboard. The Ice-Sheet Mass Balance Intercomparison Exercise (IMBIE) looks at ways to measure the Arctic and Antarctic consistently. This is a joint NASA/ESA effort to resolve discrepancies. Results confirm that both of the world's major ice sheets are losing ice, primarily in Greenland. Recent work on Greenland provides multi-sensor surface elevation data. The change rate varies, but investigators only know that because scientists have pulled together much data from different sources.

Operation Ice Bridge (OIB) is bridging the gap in data collection between ICESat-1 and ICESat-2, linking to CryoSat-2, and making key measurements for predictive models. The Arctic Radiation Icebridge Sea and ice Experiment (ARISE) is a new mission that just had its first science meeting a few weeks ago. It will go up in summer of 2014 and look at the relationship between ice cover and radiation fluxes, with cloud cover factored in. The Carbon in Arctic Reservoirs Vulnerability Experiment (CARVE) has been going on for a couple of years over Alaska. It shows high concentrations of methane and indicates that some weather has been outside the historical norms, like the October rain in Fairbanks.

NASA has created a new website to consolidate and improve access to this information and data. It provides those who are interested but not working in the profession with results in context. **did not get url, which would be helpful here; can't find it on slides and Dr. Rood said it didn't work** Dr. Kaye also discussed measurement programs. Earth System Data Records (ESDR) integrate and improve usability for other disciplines.

Looking ahead, the program hopes to encourage broader use of remote sensing in order to address polar activities in the context of global change and Earth system science. Many new remote sensing tools are increasingly available from space and aircraft, and these are not all NASA tools. The rapid change in the Arctic has generated much interest.

Discussion
Dr. Carmichael noted that there are observable measurements that are not yet done well, like absorption. The estimates that do come in do not support detailed policy analysis at this point. He wanted to know what gaps have been identified and what actions are being taken to fill them. Dr. Kaye said that much is being learned, and future satellites may address methane, for example – that would be a JAXA program. Other things are harder to address. The relationship between ice and snow, and snow on ice, has been problematic, for example, though investigators are making progress.

Dr. Rood said that the presentations indicate that the program has become more integrated, while also suggesting that there is less pressures to justify the program. He wondered if that were true, that the turf between air and space has become less of an issue. Dr. Kaye affirmed that that is the case. The program is at capacity right now, and the airborne campaign would be hard to expand. No one is asking why NASA is flying planes, but they want to know what NASA can do with those flights. It used to be that satellite work did not connect with the airborne program. That is no longer true. The airborne campaigns must now develop synergy with the satellites, which can be present longer.

Dr. Diane Wickland from NASA said that the last carbon cycle solicitation covered wetlands. In the arctic, the program will study wetlands by definition. Dr. Nolin praised the program, especially the integration and hybrid approach. She said she hoped the DS will express interest in this as well as space. Dr. Shepherd asked if there is any integrated or programmatic effort to tie this into the jet stream. Dr. Kaye replied that at least one IDS selection addresses this.

Dr. Shugart asked how the chilling relationship between the United States and Russia might affect this work. Dr. Kaye said that there could be some impact. The Arctic Council has heavy Russian involvement. There are challenges, among them the issue of flight privileges. Balloon flights have the same issue, especially for SMD's Astrophysics Division (APD). Because of diplomatic issues, this is not the time to push for expansion. However, NASA continues talking about data availability, equipment, etc., and can possibly go through Canada, Sweden, and other countries if need be.

Arctic Boreal Vulnerability Experiment (ABoVE)
Dr. Wickland discussed the ABoVE program, which studies environmental change in the Arctic and boreal regions of western North America, as well as the implications for ecological systems and society. There are significant changes occurring in the Arctic and boreal regions, which have had consequences for people, animal ecology, and infrastructure. The project focus is on vulnerability and resilience of ecosystems. Changes to these ecosystems lead to societal impacts in such areas as human health. Those impacts affect the causes of change, like land management, which then affect ecosystem changes further.

ABoVE offers compelling science in response to national priorities. Remote sensing helps document change and provide a context for field observations. The project contributes to IARPC and the President's Climate Action Plan (CAP). There is a core area of study along with possible extended areas. Satellite and airborne remote sensing will be critical to the spatial and temporal scaling of observations made from field studies. The science definition team (SDT) developed a plan that just went out for public comment, and solicitations will go out in Research Opportunities for Space and Earth Science (ROSES) 2014. The first campaign will likely be in 2016 or 2017, with the next campaign 2 years later.

Anticipated outcomes are a more complete understanding of ecosystem vulnerability and resilience to climate change in this area, and the science information required to develop options for societal responses. ABoVE will also use new satellite data products; create some custom decision support products; educate and train a new generation of scientists; increase capacity in northern communities for education and research; promote collaboration; and archive a rich legacy data set.

Discussion
There has not yet been a decision made about having another mission to model field and airborne campaigns. The Department of Energy (DOE) is a strong partner with modeling expertise. Regarding the graphics, the study is year-round, but the photographers visited in the summer. Dr. Nolin said that she looks forward to seeing how they address detecting snow under the trees, which is quite challenging. It was noted that there is a specific objective on the impact of snow on vegetation and fauna, and there are some very open canopies.

Regarding plans to train new scientists, Dr. Wickland said that there are no changes for the college-level education. The program will reach out to local communities in order to bring in people. Dr. Running added that for K-12 education, live feeds are simple and the students love them; children are fascinated with the far North.

Dr. Shugart wanted to know more about how much of the carbon in the Arctic soil is in play. Dr. Wickland replied that this is a huge question that is hard to resolve. Dr. Shugart added that this is a regional study. The Russian forest is larger and has different characteristics. He wanted to know the global implications and if the study might expand. Dr. Wickland answered that it would be helpful if what the team learns is scalable. However, that large system is not going to have an analogue. Non-U.S. satellites will be included, as everything is needed. The SDT report is new and provides more detail about vulnerability relative sensitivity, societal priorities, etc.

Dr. Dessler wondered if there are really jobs for the students being trained. This goes beyond just the ABoVE mission to encompass everything that had been discussed at the meeting. Dr. Wickland said that she asks herself that question. She has found that the fellowship students get jobs; this area of research is not shrinking, and she sees more success than failure. The fellowship application rate was stable until this past year, when it shot up. Dr. Rood added that the last National Academy of Sciences (NAS) report he worked on found no quantitative data on this, yet NAS reports keep saying that there is a shortage of scientists. His group advocated a study of the workforce, as new academic programs are being generated. The general literature suggests there are overall too many science PhDs, but there is nothing specific on Earth science. Dr. Dessler said that the students cannot all get jobs in academia. Dr. Shepherd said that a study indicated that there are too many atmospheric scientists. Dr. Dessler said that most of these students will not get academic jobs, or go into the government or work as contractors. Ms. Green said that there are many jobs outside of academia.

National Climate Assessment (NCA)

Dr. Kaye explained that ESD is involved in the NCA through its interagency coordination efforts and participation in the various groups involved, particularly the U.S. Global Change Research Program (USGCRP). The USGCRP focuses on advancing science, informing decisions, sustained assessment, and communication and education. The NCA is a huge investment on the part of the nation and community.

Dr. Allison Leidner works on the NCA for NASA. She explained that the most recent report was released on May 6. The Global Change Research Act of 1990 requires a quadrennial report under USGCRP, though this report has not always been issued; there have only been three. The third NCA:

- Assesses the science of climate changes, analyzes current trends and impacts, and projects major trends for the next 25-100 years;
- Documents impacts and responses for various sectors and regions; and
- Aims to inform public and private decision-making at all levels.

The goal is to enhance the U.S. ability to address climate change. The report was overseen by the NCA Development and Advisory Committee (NCADAC). There were also an interagency working group and chapter authors. Draft reports went through multiple reviews at various levels. The report includes climate science, regional and sectoral impacts, and responses. The top line messages are that climate change is happening now due to human causation; we are feeling its effects; it touches major aspects of our lives; and, we can do something about it. The report incorporates advancements in climate change, and provides stronger new evidence that humans-caused climate change affects people. The focus is on impacts and adaptations.

The report is policy-neutral; it reports the science and how it affects us, then provides several paths forward. NCA differs from the Intergovernmental Panel on Climate Change (IPCC) in having a specific U.S. focus, greater stakeholder involvement in developing and writing the report, and less focus on mitigation. NASA was involved in the NCA from a programmatic and scientific perspective. The Agency's observations, models, and analysis were used throughout the report, providing perspective on global context and integrated understanding. Key science contributions involved a number of NASA scientists and PIs. There will be a June workshop discussing evaluation and how to proceed.

Dr. Leidner was not aware of any climate skeptics involved in the process, but noted that the document was put out for public comment. Each of the 4-5,000 comment was addressed, and the authors did not know who presented which comments. The report release received a great deal of media attention, and there were interviews with the President, events at NASA Ames, and a big social media push. The team worked with the public affairs office to reach many different audiences.

Next up is sustained assessment. The process is complex. It shifts emphasis to stronger investments in communities, whether they be regional or sectoral, to build their capacity to do assessment. NASA strongly supports this and has led the way in supporting this process by investing in two programs. The Global Change Information System (GCIS) is meant to become a unified, web-based source for authoritative accessible and timely information about climate and global change by scientists, decision-makers, and the public.

Dr. Shepherd asked if there is an effort to move the data from the format used by scientists into something more universal. Dr. Freilich replied that this is in the BEDI objectives, especially regarding accessibility and usability. Dr. Kaye added that the goal has been to make data available independent of the source, so that users wanting NASA, NOAA, and other data should be able to obtain all of it. There will be easier searches and the capacity to build dynamically. Dr. Rood noted that there are other efforts as well. NOAA is developing the climate resilience tool kit, and he is working on another tool in partnership with CalAdapt. He and a colleague have a paper coming out on the usability of government data systems. He believes that the NCA has made a huge step forward in this area.

NASA Contribution to NCA

Dr. Leidner explained that NASA was the first agency to issue a research call to support sustained, assessment-relevant science. ESD began with an internal call for the NASA centers (the "Center Call"), and also issued an "Indicators" solicitation via ROSES. The goals were to grow the investigator community, and to make NASA expertise and capabilities available to the NCA.

The Center Call addressed three areas: enabling tools; assessment products and capabilities; and 2013 NCA sections. The initial project duration was set for 27 months, and selection was for 14 projects with a total budget of $7.5 million, though the budget became $8.9 million. The projects included four enabling tools, nine assessment capabilities, and one writing proposal. All but the writing proposal were approved to continue another year. The assessment capabilities fell into three subcategories: environmental change and weather; urban infrastructure, vulnerability, and public health; and physical science.

Dr. Schmitt said that he was seeing a lot of modeling, and wondered what should be done for the long-term. Later scientists will want data, not models. Dr. Leidner said that that is an issue, and also a question for the larger Earth science program at NASA. Dr. Kummerow said that one of NASA's strengths is that it is seen as neutral. The assessments are a danger zone in that NASA does not have final say on the content. Therefore, NASA should take a very specific piece of this and identify the contribution. There is no such thing as a policy-neutral document. Dr. Leidner said that NASA looked at how its scientists use the report and reflected the nature of what NASA science has to show.

Dr. Freilich added that NASA is an executive branch agency. The executive branch implements. When NASA is directed to do something, the Agency has little ground to say otherwise. There is advancement of Earth science in everything ESD does. Therefore, one cannot point to an indicator call and say that it only supports a given policy. ESD attempts to walk that line and works hard to open earmarked calls to the science community. The Division cannot limit what it does once it is asked.

Dr. Kaye said that he worries about this. NASA does not make policy or regulate, so the Agency does provide objective science. But it must be careful to separate science from political choices. The NCA provides some protection, as it is mandated. However, NASA cannot let the science be seen as supporting a particular objective. He says that science does not tell us what to do, it tells us what is happening and why, and maybe what the future will be and the paths we might take. The dilemma is in maintaining separation between Administration executive orders and the science. It was added that one reason for all the review is that the Agency looks for policy sensitivities to ensure that its data are not used in an inappropriate way. NASA seeks an accurate representation of the science.

In beginning her portion of the presentation, Dr. Tsaoussi said that one goal for NASA and the NCA was to solicit contributions to develop and test potential indicators that address needs stated in the NCA and that draw from NASA products. She presented some of the Indicator Call criteria, noting the importance of identifying a team leader. The 14 awards were funded at $2.4 million and began in summer of 2013. This is not a continuing, long-term program. The National Climate Indicators System (NCIS) is supporting the Global Context Indicators (GCI).

The implementation is occurring in three phases: Phase 1 is the pilot system, which has an unreleased draft report; Phase 2 is the full launch; and, Phase 3 is ongoing, for growth and continual evaluation. The criteria are very difficult to meet, and the pilot must be able to be implemented immediately. NASA wants to develop new indicators. The review panels looked for specific contributions to climate change. The call succeeded in getting different teams together and looking at a variety of data sets. There were social scientists and physical scientists involved, for example. Among the indicators to be reviewed are lightning, dust storms, agricultural productivity, and land cover. The themes are very diverse.

Many participating scientists reported that they struggled with climate attribution. For example, there are diverse opinions about lightning and whether it is related to climate change. Every project has targeted users. Some are broad, and some are very specific. Most projects developed new products, but some were dealing with new communities and issues of how to reach them and apply the indicators. All of them are looking to develop and understand evaluation tools. There is also much concern about how the data will be disseminated. The big question is how they connect to the national system and the future NCA.

Dr. Tsaoussi next showed a list of the projects and discussed examples looking at lake temperatures in the West, health and other impacts of heat waves in urban areas, polar bear migration patterns, and whether the Dust Bowl could happen again. The focus is not necessarily on the United States; many NASA data sets are global.

Dr. Running noted that there will still be a struggle with the extent to which the audience is scientists seeking data, versus simplified information for the public. He did not believe the NCA has yet shown a clear understanding of where indicators should be.

Earth Science Integration Discussion

Dr. Running raised the issue of the ESS role in the global integrated ES modeling. He showed the Bretherton Diagram of 1986, which was very influential at the time in defining Earth science. There were

almost no global data. Now, Earth Science Data Operations (ESDO) covers mission operations, science operations, and data. Most of the data come from ESD. Three years ago, ESS heard from a lot of modeling teams around NASA Earth science. The Subcommittee determined that efforts should be made to integrate more fully the various elements into a complete, coupled, and interactive description of the Earth system. Future activities should focus on the coupling between the elements of the dynamical system.

His question was whether now, in 2014, ESS wanted to revisit this and provide more specific advice? Is this something for the next meeting? This is a question for all U.S. science agencies, and ESS should determine both NASA's role and whether the Subcommittee has something to say. USGCRP ought to be the home for a wider national strategy.

Dr. Shepherd said that NSF has a program addressing this kind of thing, though he was not sure how much they deal with modeling. That would be a natural place for ESS to connect as a good starting point. Dr. Kummerow said that the issue was framed too broadly. He would like to see NASA coupling in with the integrated science areas.

Dr. Shugart had some concerns about how stable the models will be if they are combined. He added that a lot of work is done comparing models to each other to determine the extent to which they agree. He feels strongly that NASA's efforts would be better spent in using the models to generate hypotheses. Dr. Rood said that ESS should get an update on the modeling projects. He wants to know what the program people in NASA see as the goal in their modeling and whether the models address those goals. NASA has had major investments in infrastructure that pay off, though often for NOAA. This is worth revisiting, but he is not as interested in the different models as he is in hearing the strategic place for modeling in NASA. Dr. Kaye said that the days of comparing models should be over. For some of the regional models, NASA is trying to apply what has been done with global models. Observations and modeling must be connected. The people familiar with the observations are best positioned to be the bridge to the modeling effort. New kinds of observations can drive a modeling effort.

Dr. Nolin said that she likes the idea of thinking about it in an integrated way. NASA has demonstrated very well that it is integrated across scales. That scaling idea is something ESS might want to discuss. Dr. Running observed that the space/time transformations from one scale to another never seem to fit right. Dr. Rood noted that technology and software allow investigators to couple to modeling that supports missions addressing storm surge. One could imagine that as a strategy for coupling models not so much as models as for meeting the needs of other communities. Dr. Shugart said that he has examples of modelers obsessed with modeling. Dr. Running said that the maturity and the protocols for model testing vary. There are similar issues in other disciplines. ESS has illustrated enough collective interest to frame it for ESD to present at the next meeting. Dr. Tsaoussi added that there could be a quick teleconference to frame the next agenda, and it would not have to be a public meeting.

Findings and Recommendations

Dr. Running presented a page of statements that had been sent to him by ESS members, clustered by topic area. He asked the Subcommittee to think of where they might have an impact on near-term decision-making.

On the topic of "reinstatement of OCO-3 as an important and cost effective deployment of that sensor, providing back-up and a synergistic data stream to OCO-2," Dr. Freilich pointed out that if Congress chooses not to fund this budget line, reinstatement would require that something else be eliminated. Dr. Running noted that a recommendation is not binding.

Next, the Subcommittee agreed to endorse the ISS program and encourage ESD to continue using this platform. Dr. Freilich suggested that the comment state that this is something ESS finds intriguing, with a request for more detail at the next meeting. That could lead to a more specific statement.

Several formal observations were made. The first was that ESS finds the value and success of GLOBE to be directly related to the connection between PIs and teachers. Next, ESS wanted to recognize the success of the SMAP early adopter program and suggest that ESD implement similar programs for future missions. The Subcommittee also endorsed the Venture Class program. Several ESS members sent Dr. Running comments about the SLI, but it was determined that this was a bureaucratic item having to do with ESS receiving the scoping document once it is issued. The Subcommittee agreed to praise ESD's five 2014 launches and other mission elements, and endorsed the ROAM activities. ESS decided not to comment on risk management at this time and determined that while it would be helpful to learn more about ESD's technology efforts at a future meeting, there was no finding to be made at this time on the topic of technology and budgetary balance.

There was much discussion about what ESS should say on the topic of education. Dr. Carmichael noted that there are no metrics on the impact of STEM education. There must be a real education strategy. Dr. Shepherd was hesitant to make a recommendation without more information, but he wanted to capture the notion of NASA reaching under-represented groups in grades K-12. There was also concern that the ESS members did not have the background to make an informed recommendation on K-12 education. Dr. Running advised having the topic on the agenda for the NAC meeting.

Dr. Rood wanted to acknowledge that the Arctic science team had done a good job of integration in regard to pressing research problems. This was to go into the letter as an observation. Regarding the NCA, it was noted that this effort was ongoing. Although there was some interest in celebrating success, Dr. Freilich cautioned that if ESS were to weigh into the interagency area, there could be some pushback from other agencies.

With the NRC soon to begin work on the next DS, ESS decided that it was important to provide input. Dr. Freilich provided the NRC with a list of topics and questions, which ESS reviewed. The list is as follows:

- Decadal Survey recommendations will not be the definitive word on the ESD program scope
    - Earth observation from space is important, thus Administration, Congress have specific equities
    - ESD will be directed to implement sustained measurements in support of NOAA, USGS – ambiguity regarding requirements/capabilities/risks
- ESD budget will not increase substantially, and may decrease
- Mission costs, schedules, can only be pre-defined/controlled in competitively selected, cost/schedule-constrained, programs (e.g., Venture Class) – not in directed, systematic, missions
    - Directed missions to NASA Centers are essential to the Agency
- Venture-Class is now an integral part of ESD culture
- Named-mission backlog from 1st Decadal Survey is substantial
- Recommend the target budgetary balance between Flight, Non-Flight
- In the Non-Flight portion of the program, recommend the target balance between R&A, Applied Science, and Technology elements
- In the Flight portion of the program, recommend the target budgetary balance between systematic/directed, and cost/schedule-constrained competed, mission programs
    - Is there a maximum acceptable mission cost ("Flagships")?
    - Should ESD spin up other Venture-like programs, with different caps?
- Flight mission architecture/approach recommendations
    - Engineering investments in common s/c? "Small-sats/constellations"?

- Provide decision principles for balancing new measurements and time series extensions of existing data sets
    - ESD budget will NOT increase
    - Other agencies will NOT transition measurements from ESD
    - How to account for international missions/programs, some long-term?
- Revisit priorities of named missions from 1st Decadal Survey
- Change scope(s) of R&A, Applied Sciences, Technology programs?

When reviewing this list, ESS made the following comments:

- Dr. McCormick would add something about specificity of instrument/approach/technique, and mention the traceability matrix.
- Dr. Kummerow wanted something aside from the flight/nonflight construct.
- Building on Dr. Freilich's statement that he wanted to remind them that many named missions were not being developed, Dr. Running said that ESS would recommend that the DS panel re-examine the named missions that have not yet moved into development and determine what is still relevant.

Dr. Running decided that there was enough to work with here and said he would develop language on it. The letter would have a small, straightforward comment about early adopters. The remaining comments were observations. He would send a draft to the members within a week, and he hoped to have the document finalized in time for the NAC meeting in July.

Closing Remarks/Adjourn

Dr. Running thanked the members and NASA, then adjourned the meeting at 3:57 p.m.

Appendix A
Participants

Committee members
Steve Running, ESS Chair, University of Montana
Roland Burgmann, University of California, Berkeley
Greg Carmichael, University of Iowa
Andrew Dessler, Texas A&M
Efi Foufoula-Georgiou, University of Michigan
Sivaprasad Gogineni, University of Kansas
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Appendix B
ESS Membership

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Appendix C
Presentations

1. NASA Earth Science Division Update, M. Freilich
2. Sustainable Land Imaging Program Study, M. Freilich, S. Volz, D. Jarrett
3. Education and Communication in NASA Earth Science, M. Freilich, M. Y. Wei
4. Radiation, Ozone, Atmospheric Measurements (ROAM), M. Freilich, S. Volz
5. NASA's Arctic Science Coordination, J. Kaye, T. Wagner, D. Wickland
6. The Arctic Boreal Vulnerability Experiment (ABoVE), D. Wickland
7. Climate Change Impacts in the United States: The Third National Climate Assessment, J. Kaye
8. Overview: The Third National Climate Assessment, A. Leidner
9. Supporting the National Climate Assessment's Sustained Assessment Process: NASA NCA Center Call, A. Leidner
10. NASA's Climate Indicators, L. Tsaoussi

Appendix D
Agenda

NAC Earth Science Subcommittee

NASA Headquarters
300 E Street SW, Washington, DC.

28-May-2014 @ MIC 3A

8:30	8:40	Opening remarks	L. Tsaoussi
8:40	8:45	Meeting charge	S. Running
8:45	10:30	Earth Science Division Update	M. Freilich
10:30	10:45	Coffee Break	
10:45	12:00	Sustained Land Imaging	M. Freilich/S. Volz/D. Jarrett
12:00	12:30	Discussion	ESS Members
12:30	*1:30*	*Lunch*	
1:30	2:30	EPO approach	M. Freilich/ M.-Y. Wei
2:30	2:45	Discussion	ESS Members
2:45	3:00	Coffee Break	
3:00	4:00	Climate sensors & products	M. Freilich/S. Volz
4:00	4:45	Discussion	ESS Members
4:45	5:15	Public Comment	
5:15		Adjourn	

29-May-2014 @ MIC 3A

8:30	8:45	Session Overview	S. Running
8:45	9:30	Ethics Training	T. Hayes
9:30	10:15	Arctic Science Coordination	J. Kaye/T. Wagner
10:15	10:30	Coffee Break	
10:30	11:15	National Climate Assessment (NCA)	J. Kaye/A. Leidner/ P. Jacobberger-Jellison
11:15	11:45	NASA Contribution to NCA	J. Kaye/A. Leidner/L. Tsaoussi
11:45	12:30	Discussion	ESS Members
12:30	*1:30*	*Lunch*	

1:30 – 2:30	Earth Science Integration Discussion	S. Running/ESS Members
2:30 – 3:30	Findings and Recommendations	ESS Members
3:35	Closing Remarks/Adjourn	S. Running/L. Tsaoussi