Exploring Commercial Opportunities to Maximize Earth Science Investments

Statement of

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Good Morning Chairman Babin, Chairman Bridenstine, Ranking Members Edwards and Bonamici, and members of the subcommittees. I am Dr. Tony Busalacchi and I am Director of the Earth System Science Interdisciplinary Center and Professor of Atmospheric and Oceanic Science at the University of Maryland. Prior to coming to the University of Maryland 15 years ago, I was a civil servant for 18 years at the NASA Goddard Space Flight Center (GSFC), the last 10 years of which I was a laboratory chief and member of the Senior Executive Service. While at Goddard I also served as the source selection official for the SeaWiFS Ocean Color Data Buy from Orbital Sciences Corporation that is directly relevant to this hearing.

Presently, I also serve as the Co-Chair of Decadal Survey for Earth Sciences and Applications from Space being carried out by the National Academies of Sciences, Engineering, and Medicine. The report from this study will provide the sponsors--NASA, NOAA and the USGS--with consensus recommendations from the environmental monitoring and Earth science and applications communities for an integrated and sustainable approach to the conduct of the U.S. government's civilian space-based Earth-system science programs.

The decadal survey's prioritization of research activities will be based on our committee's consideration of identified science priorities; broad national operational observation priorities as identified in U.S. government policy, law, and international agreements (for example, the 2014 National Plan for Civil Earth Observation) and the relevant appropriation and authorization acts governing NASA, NOAA, and USGS; cost and technical readiness; the likely emergence of new technologies; the role of supporting activities such as in situ measurements; computational infrastructure for modeling, data assimilation, and data management; and opportunities to leverage related activities including consideration of interagency cooperation and international collaboration. With the expectation that the capabilities of non-traditional providers of Earth observations will continue to increase in scope and quality, the decadal survey has also been asked to suggest approaches for evaluating these new capabilities and integrating them, where appropriate, into NASA, NOAA and USGS strategic plans. The committee will also consider how such capabilities might alter NOAA's and USGS's flight mission and sensor priorities in the next decade and beyond.

Before continuing with my testimony I should note that I am speaking on my own behalf today, not on behalf of the other co-chair of the decadal survey--Dr. Waleed Abdalati of the University of Colorado--or the survey's steering committee that is being assembled as we meet today. Nothing in my testimony today should be construed as indicating anything about what the decadal survey committee may recommend when our report is published in the summer of 2017.

Following the suggestion in the committee's letter inviting me to testify, I will organize my testimony around the following questions:

1. *What are the opportunities and challenges associated with potential public private partnerships for NASA's Earth science program?*
2. *What were the key lessons learned from prior public private partnerships, such as Sea-viewing Wide Field-of-view Sensor (SeaWiFS), and what were the most challenging aspects?*
3. *Provide a summary of prior National Academies work relevant to NASA Earth observations and partnerships with commercial entities.*
4. *What processes and policies are needed to identify if public private partnerships should be used and when, and how they should be evaluated? What, if any, are the next steps for Congress?*

1. What are the opportunities and challenges associated with potential public private partnerships for NASA's Earth science program?

Public-private partnerships have the potential for cost savings to the government and the possibility for accelerating innovation. While this potential may exist it is far from being realized and proven possible.

NASA's Earth Science Division (ESD) conducts a wide range of satellite and sub-orbital missions in order to better understand Earth as an integrated system. Earth observations provide the foundation for critical scientific advances and data products derived from these observations that are used for an extraordinary range of societal applications including resource management, weather forecasts, climate projections, agricultural production, and natural disaster response. ESD develops its observing strategy in response to Congressional and Executive Branch direction and through consultation with the scientific community. In particular, the consensus views of the scientific community as expressed in Academies' decadal survey reports are used to guide future investments.

In addition to the ambitious plans recommended to NASA in the inaugural decadal survey, Earth Science and Applications from Space (2007),[1] starting in Fiscal Year 2014 NASA was directed to assume additional responsibilities for sustaining a number of measurements previously assigned to other agencies.[2] With these constraints and against the backdrop of an austere budgetary environment that is likely to persist for the foreseeable future, and facing increased demands for Earth information products critical to the nation's welfare, the Earth Science Division is actively examining evolving opportunities to use smaller and less costly spacecraft, spacecraft constellations, hosted payloads, and "missions of opportunity"—all with the objective of "doing more with less." For example, following a recommendation in the 2007 decadal survey, ESD developed a new "Venture" class series of science-driven, competitively selected, comparatively low-cost missions that are providing more frequent opportunities for investment in innovative Earth science using smaller satellites, the International Space Station, hosted payloads, and sub-orbital platforms.

The private sector is rightfully known as an engine of innovation. This is seen, for example, in the myriad of companies that are now developing novel Earth imaging capabilities. Public-private partnerships *may* offer a way for NASA ESD to acquire—at lower cost—the data it and the nation require. While this approach may prove practical in the case of Earth imaging where there is over 60 years of heritage, in my view there is no *a priori* reason to believe it will prove practical for new remote-sensing methodologies and technologies. As I discuss later in my

[1] NRC. 2007. *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond.* The National Academies Press, Washington, D.C.

[2] These include Precision Altimetry following the launch of Jason-3; Solar Irradiance (TSIS-2 and follow-on missions transferred to NASA in FY14); Earth Radiation Balance (RBI instrument--RBI being developed by NASA for flight on JPSS-2 (~April 2019 instrument delivery date); and the OMPS-L instrument for ozone profiles. In addition, the FY14 and FY15 President's budget for NASA called for design and initiation of an affordable, sustained, Land Imaging Satellite System (with USGS) to extend the Landsat data record for decades.

testimony, issues of data access and data quality pose particular challenges in a government partnership with a profit-generating private entity.

2. **What were the key lessons learned from prior public private partnerships, such as Sea-viewing Wide Field-of-view Sensor (SeaWiFS), and what were the most challenging aspects?**

SeaWiFS[3] was a science data buy in which NASA served as the anchor tenant to a private entity that was responsible for building and launching a spacecraft and instrument with particular capabilities. While my testimony today focuses on SeaWiFS, it should be recognized that other types of public-private partnerships have been successfully demonstrated; for example, the hosted payload model whereby NASA utilizes available capacity on commercial satellites to accommodate an additional instrument(s).

From a scientific perspective, SeaWIFS was a grand success in terms of the quality of the global ocean color data that was acquired and the subsequent research on marine ecosystems. The structure of the data buy was such that NASA had insight-without-oversight. Overall, this strategy worked well primarily because our SeaWiFS Project maintained a healthy working relationship with Orbital Sciences Corporation (OSC) and the instrument vendor, Hughes/Santa Barbara Research Center, even though there were some serious problems with the launch vehicle, spacecraft and sensor resulting in a four-year launch delay. OSC also overran their budget, but not at government expense. While the whole process was very stressful for all parties, it did result ultimately in the provision of quality data. It is worth noting, however, that a less harmonious relationship between both parties could well have led to contract cancellation.

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[3] Subtle changes in ocean color signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications. It became apparent to the oceanographic community that because of the dynamic nature of the world's oceans and climate, and the importance of the ocean's role in global change, a follow-on sensor to the Coastal Zone Color Scanner (CZCS) should be flown…The SeaWiFS Project was designated to develop and operate a research data system to gather, process, archive, and distribute data received from an ocean color sensor…The data was procured as a "data buy" from a private contractor, Orbital Sciences Corporation (OSC), which subcontracted with the Hughes Santa Barbara Research Center (SBRC) to build the SeaWiFS ocean color sensor. OSC built and launched the SeaStar satellite carrying the sensor on August 1, 1997. Following launch, the satellite's name was changed to OrbView-2(OV-2), and operations were turned over to ORBIMAGE, a spinoff of OCS. From the NASA SeaWiFS brochure: http://oceancolor.gsfc.nasa.gov/SeaWiFS/BACKGROUND/SEAWIFS_970_BROCHURE.html.

Even though SeaWIFS was technically a data buy from the private sector, the project would not have been a success without the engineering support from NASA's Goddard Space Flight Center (GSFC). Considerable support was provided by GSFC engineers in areas such as the power system, attitude control system, navigation system, component quality control. Although there was some heritage in ocean color remote sensing from the proof of concept Coastal Zone Color Scanner, the fact that SeaWiFS was a totally new sensor employing a novel lunar calibration underscored the need for expert engineering support from an organization like NASA Goddard.

As part of the ocean color data buy arrangement, NASA was also responsible for science data processing, on-orbit sensor calibration, and product quality control. Key to the success of the research quality of the data was the sustained participation of the science community, a project office staffed by experienced scientists with a vested interest in the mission, and development of the necessary infrastructure that did not exist when the project started. *In any such public-private partnership going forward this range of activities needs to be supported and sustained.*

Most of the infrastructure (including staff, which is critical) that we put in place under SeaWiFS remains in place today and has been expanded to support development of successor instruments, including MODIS[4] and its successor, VIIRS,[5] which is currently manifested on Suomi National Polar-orbiting Partnership, or Suomi NPP. VIIRS is also a key instrument on NOAA's JPSS[6] system going forward. This is relevant to the topic of routine or sustained observations where the science or support to societal benefit areas requires the data stream to be stable, continuous and calibrated for years to decades. If such long-term data records and related research is the goal, then a long-term commitment is required.

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[4] MODIS (or Moderate Resolution Imaging Spectroradiometer) is a key instrument aboard NASA's Terra (originally known as EOS AM-1) and Aqua (originally known as EOS PM-1) satellites.

[5] Currently flying on the Suomi NPP satellite mission, VIIRS (Visible Infrared Imaging Radiometer Suite) generates many critical environmental products about snow and ice cover, clouds, fog, aerosols, fire, smoke plumes, dust, vegetation health, phytoplankton abundance and chlorophyll. VIIRS will also be on the JPSS-1 and JPSS-2 satellite missions.

[6] The Joint Polar Satellite System (JPSS), the Nation's next generation polar-orbiting operational environmental satellite system, is a collaborative program between NOAA and its acquisition agent, NASA. JPSS was established in the President's Fiscal Year 2011 budget request as the civilian successor to the restructured National Polar-orbiting Operational Environmental Satellite System (NPOESS).

Maintaining consistent and traceable time series between missions with, for example, different sensor designs and different orbits presents many challenges. It is not clear how this can be accomplished by a public-private partnership given that every mission is competed and executed independently. This problem is magnified by the need for reprocessing all data sets using standardized algorithms and calibration methodologies. Developing close working relationships and sharing data with other space agencies has always been NASA's policy. NASA has also made data freely available. Under commercialization, these relationships and policies would need to be maintained. The private sector (U.S. and international) tends to consider code, sensor design information, and test data as proprietary—potentially a huge stumbling block to data consistency and continuity.

In order for OSC to market ocean color data, NASA did not have free and open access to the data. Overall, the data access agreement for research worked well—that is researchers had to register and verify they were only using the data for research and not for commercial purposes. Even though most of the research with SeaWiFs data was done in a delayed mode, we were able to provide real-time data in support of research cruises/field campaigns. Going forward any public-private partnership will need to develop a cost model based on data latency and resolution.

3. **Provide a summary of prior National Academies work relevant to NASA Earth observations and partnerships with commercial entities.**

The Academies has published several reports that touch on the issues of this hearing, including *Resolving Conflicts Arising from the Privatization of Environmental Data* (2001); *Toward New Partnerships In Remote Sensing: Government, the Private Sector, and Earth Science Research* (2002); and *Assessing the Requirements for Sustained Ocean Color Research and Operations* (2011).[7] Of particular note, *Toward New Partnerships* and *Assessing the Requirements for Sustained Ocean Color Research and Operations* include an examination and lessons learned from NASA's

[7] NRC. 2001. *Resolving Conflicts Arising from the Privatization of Environmental Data*. The National Academies Press, Washington, D.C.; NRC. 2002. *Toward New Partnerships In Remote Sensing: Government, the Private Sector, and Earth Science Research.* The National Academies Press, Washington, D.C.; and NRC 2011. *Assessing the Requirements for Sustained Ocean Color Research and Operations.* The National Academies Press, Washington, D.C.

Science Data Buy (SDB) for SeaWiFS, a data buy for which, as previously mentioned, I am quite familiar with as I was the SeaWiFS source selection official while serving as head of NASA Goddard's Laboratory for Hydrospheric Processes.

Here, I would like to touch briefly on two specific challenges that need to be addressed for commercial entities to become viable partners in NASA's Earth science research and applications programs.

Full and Open Access to Data:

For obvious reasons, a commercial entity entering into a partnership to provide NASA observations must have a business model that promises a tangible financial return. Typically, whether the entity is producer or distributor, they will require restrictions on access to data. However, as noted in *Toward New Partnerships*, full and open access to data and the opportunity both to replicate research findings and to conduct further research using the same data are critical to scientific research.

In the case of SeaWiFS, which generated ocean color data of commercial and scientific value, the contract between NASA and the data provider, Orbital Sciences Corporation (OSC), had NASA retaining all rights to data for research purposes, and ORBIMAGE, a spinoff of OSC, retaining all rights for commercial and operational purposes. The contract included an embargo period of 2 weeks from collection for general distribution of data to research users to protect ORBIMAGE's commercial interest. Notably—and the key to making this arrangement practicable in my view—the commercial value of ocean color data to the fishing industry dissipates rapidly while the scientific value is not impacted substantially by short delays in data distribution.

With respect to access and utilization of its science data, NASA has, as a matter of longstanding policy and practice, archived all science mission data products to ensure long-term usability and to promote wide-spread usage by scientists, educators, decision-makers, and the general public. NASA has called attention to this policy in particular with respect to Earth science data, stating, "Perhaps the most notable endeavor in this [open access] regard is the Earth Observing System Data and Information System (EOSDIS), which processes, archives, and distributes data from a large number of Earth observing satellites and represents a crucial capability for studying the Earth system from space and improving prediction of Earth system change. EOSDIS consists of a set of processing facilities and data centers distributed across the United States that serve hundreds of thousands of users around the world."[8]

Ensuring the Quality of the Data and Maximizing the Nation's Return on Investment

In *Assessing the Requirements for Sustained Ocean Color Research and Operations*, it is noted that, "Building and launching a sensor are only the first steps toward successfully producing ocean color radiance and ocean color products. Even if the sensor meets all high-quality requirements, without stability monitoring, vicarious calibration, and reprocessing capabilities, the data will not meet standards for scientific and climate-impact assessments." The report goes on to note that: "To a large extent, success of the SeaWiFS/MODIS era missions can be attributed to the fact that they incorporated a series of important steps, including: pre-flight characterization, on-orbit assessment of sensor stability and gains, a program for vicarious calibration, improvements in the models for atmospheric correction and bio-optical algorithms, the validation of the final products across a wide range of ocean ecosystems, the decision going into the missions that datasets would be reprocessed multiple times as improvements became available, and a commitment and dedication to widely distribute data for science and education (e.g., Acker et al.,[9] 2002a; McClain, 2009;[10] Siegel and Franz, 2010[11])."

The report's conclusion, which I strongly endorse, is that SeaWiFS' success in producing high-quality data was due to the commitment by NASA to all critical steps of the mission, including pre-flight characterization, on-orbit assessment of sensor stability and gains, solar and lunar

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[8] See "Access and Utilization of NASA Science Data: Stewardship for the Integrity and Preservation of Science Data as a Worldwide Resource," available online at: http://www.nasa.gov/open/plan/science-data-access_prt.htm.

[9] Acker, J.G., R. Williams, L. Chiu, P. Ardanuy, S. Miller, C. Schueler, P. Vachon, and M. Manore. 2002a. Remote sensing from satellites. *Encyclopedia on Physical Science and Technology* 14(3): 161-202.

[10] McClain, C.R. 2009. A decade of satellite ocean color observations. *Annual Review of Marine Science* 1: 19-42.

[11] Siegel, D.A. and B.A. Franz. 2010. Oceanography: A century of phytoplankton change. *Nature* 466: 569-570.

calibration, vicarious calibration, atmospheric correction and bio-optical algorithms, product validation, reprocessing, and widely distributed data for science and education.

It is my understanding that the organizers of this hearing, the Space and Environment Subcommittees of the Committee on Science, Space, and Technology of the U.S. House of Representatives have a particular interest in the potential role of public-private partnerships in sustaining Earth science measurements beyond the nominal lifetime of the mission/instrument that provided a first demonstration of capability/proof of concept. Here I wish to note the particular challenges that would need to be met—whether by NASA or in partnership with a private entity—with respect to trend detection and the creation of data records that can be used to inform decision makers.

Monitoring over long time periods is essential to detecting trends, whether for solar radiance, land-cover change, or ozone destruction. Long-term monitoring is also necessary to understand critical processes that are characterized by low-frequency variability. Because changes on a wide range of time and space scales affect Earth, it is not possible to determine *a priori* and with certainty the types of observations that should be made and the appropriate sampling strategy. An observing system may very well reveal unexpected phenomena such as the large-scale, low-frequency El Niño/Southern Oscillation of sea surface temperature as is happening right now in the tropical Pacific Ocean, and scientific opportunities are lost if the observing strategy cannot adapt accordingly.[12]

A Finding in *Towards New Partnerships* gives further detail on the challenge in creating an observing system capable of trend detection. There it is stated, "Continuity of remote sensing observations over long periods of time is essential for Earth system science and global change research, and it requires that scientists have access to repeated observations obtained over periods of many years…As scientists expand their use of data from both public and private sources, problems may arise in combining remote sensing data from multiple sensors with different capabilities and characteristics." These statements are consistent with an earlier report

[12] See Chapter 10, "Issues, Challenges, and Recommendations," in NRC 2000. *Issues in the Integration of Research and Operational Satellite Systems for Climate Research: Part I. Science and Design.* National Academies Press, Washington, D.C.

from the Academies, where it is noted, "It takes a special effort to preserve the quality of data acquired with different satellite systems and sensors, so that valid comparisons can be made over an entire set of observations. There are few examples of continuous data records based on satellite measurements where data quality is consistent across changes in sensors, even when copies of the sensor design are used. Sensor characterization and an effective, ongoing program of sensor calibration and validation are essential in order to separate the effects of changes in the Earth system from effects owing to changes in the observing system…Data systems should be designed to meet the needs for periodic reprocessing of the entire data set. An aggressive, science-driven program to ensure long-term data quality and continuity is very important."[13]

4. **What processes and policies are needed to identify if public private partnerships should be used and when, and how they should be evaluated? What, if any, are the next steps for Congress?**

Drawing on the lessons learned from the past, the most important next step is to establish a series of best practices to guide future public private partnerships for Earth remote sensing. In my experience, the following are characteristics of successful partnerships between NASA and a private-entity:

- The establishment of an appropriate insight/oversight model with the commercial partner.
    - What worked well for the SeaWiFS science data buy was the arrangement where NASA maintained insight, but not oversight, of the project. "Insight" is a monitoring activity, whereas "oversight" is an exercise of authority by the Government. SeaWiFS was a cost-sharing collaboration between NASA and Orbital Sciences Corporation (OSC) wherein NASA Goddard specified the data attributes and bought the research rights to these data, maintaining insight, but not oversight, of OSC. The SeaWiFS Project at GSFC was responsible for the calibration, validation, and routine processing of these data. OSC provided the spacecraft, instrument, and launch, and was responsible for spacecraft operations for five years at a fixed price, while retaining the operational and commercial rights to these data. In order to protect OSC's data rights, the release of research

[13] Ibid.

data was delayed, unless near-real time access is necessary for calibration and validation activities.[14]

- NASA access to algorithms and instrument characterization; NASA access to and reuse of data; and the establishment of an appropriate data archive.
    - Turning data into information of value to both a commercial entity *and* to the science community--now and in the future--requires detailed knowledge of how the raw data are generated, the algorithms that are used to process the data and generate higher-level data products, and control of how the data are archived. Taking these steps ensures the quality of the data and enables it to be characterized in a way that permits it to be combined with similarly well-characterized data from different instruments. It also facilitates future reprocessing in light of new knowledge and newer algorithms.
- Need for science teams as part of a plan to maximize the utility of the data
    - The establishment of a science team early in the development of a NASA Earth observation mission is a familiar and well-grounded recommendation. Once established, early science efforts (e.g. on prototype systems and/or synthetic datasets) can contribute directly to engineering and systems analyses. They can also optimize algorithms through competition (e.g. retrieval algorithms, extrapolations, etc.); provide a conduit to the user community; and provide timely notice to the research community, which would rapidly expand the user base. In addition, they can exploit the science perspective for system refinements (i.e. for follow-on missions), validation, and error detection.[15]
- Technical readiness as a measure of what observation methodology may be ripe for a public private partnership.
    - In the case of Earth imaging there is over six decades worth of heritage on the design of such sensors. This has provided the opportunity for significant core competencies to be developed in the private sector thus enabling public private

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[14] For a fuller discussion, see McClain, C.R., Feldman, G.C., and Stanford B. Hooker. *An overview of the SeaWiFS project and strategies for producing a climate research quality global ocean bio-optical time series.* Deep Sea Research II, 51, 5-42, 2004.

[15] See Appendix D, "The Role of Science Teams," in NRC. 2000. *Ensuring the Climate Record from the NPP and NPOESS Meteorological Satellites.* The National Academies Press, Washington, D.C.

partnerships. Those technologies that are mature are likely the ones that may be most amenable to a public private partnership. Conversely, the more novel the technology or newer the data stream may well require more government involvement to draw on a wider base of expertise for sensor characterization, calibration, validation, and science data processing and reprocessing.

- Commercial demand and market for the data is key to cost savings to the government.
    - If the government is the sole user of the data, there is little incentive for a public private partnership. In the example of SeaWiFS, the cost to the government was reduced by OSC's intent to sell the real-time data to the commercial fishing industry. Transition across basic research to applied research to the development of products and applications is not easy and not fast. However, the extent to which this can be accelerated in support of a range of societal benefit areas, including, for example, agriculture, transportation, fishing, recreation, and land use, will determine the non-governmental demand for the data and potential cost savings to the government.

I hope that even these brief comments demonstrate that obtaining the kinds of data required by scientists for critical Earth science applications and for credible forecasts of the future state of the Earth system requires careful attention from the design of an instrument to the plan for continuity to stewardship of the data. Yet, the science community operates in a way that typically differs dramatically from that of the commercial remote sensing industry. Public-private partnerships offer an alternative—and potentially less costly—method to acquire Earth observations. However, with SeaWiFS as a guide, a successful public-partnership may be realized only in limited circumstances and only with careful attention to the particular needs of both profit-making entities and the scientific community.