

**EXPLORING COMMERCIAL OPPORTUNITIES TO
MAXIMIZE EARTH SCIENCE INVESTMENTS**

JOINT HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND
SUBCOMMITTEE ON ENVIRONMENT

COMMITTEE ON SCIENCE, SPACE, AND
TECHNOLOGY

HOUSE OF REPRESENTATIVES

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**EXPLORING COMMERCIAL OPPORTUNITIES
TO MAXIMIZE EARTH SCIENCE INVESTMENTS**

TUESDAY, NOVEMBER 17, 2015

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE &
SUBCOMMITTEE ON ENVIRONMENT
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittees met, pursuant to call, at 10:00 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee on Space] presiding.

Congress of the United States
House of Representatives

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

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Subcommittees on Space and Environment

***Exploring Commercial Opportunities to Maximize Earth
Science Investments***

Tuesday, November 17, 2015
10:00 a.m. -- 12:00 p.m.
2318 Rayburn House Office Building

Witnesses

*Dr. Scott Pace, Director of the Space Policy Institute, George Washington
University*

Dr. Walter Scott, Founder and Chief Technical Officer, DigitalGlobe

Mr. Robbie Schingler, Co-Founder and President, PlanetLabs

*Dr. Samuel Goward, Emeritus Professor of Geography, University of Maryland
at College Park*

*Dr. Antonio Busalacchi, Professor and Director of the Earth System Science
Interdisciplinary Center, University of Maryland*

**U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE
SUBCOMMITTEE ON ENVIRONMENT**

Exploring Commercial Opportunities to Maximize Earth Science Investments

HEARING CHARTER

Tuesday, November 17, 2015
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

Purpose

The Subcommittees on Space and Environment will hold a joint hearing titled *Exploring Commercial Opportunities to Maximize Earth Science Investments* on Tuesday, November 17, 2015, starting at 10:00 a.m. in Room 2318 Rayburn House Office Building. The hearing will explore ways NASA can satisfy Earth science data requirements through public-private partnerships, including commercial capabilities.

Witnesses

- **Dr. Scott Pace**, Director of the Space Policy Institute, George Washington University
- **Dr. Walter Scott**, Founder and Chief Technical Officer, DigitalGlobe
- **Mr. Robbie Schingler**, Co-Founder and President, PlanetLabs
- **Dr. Samuel Goward**, Emeritus Professor of Geography, University of Maryland at College Park
- **Dr. Antonio Busalacchi**, Professor and Director of the Earth System Science Interdisciplinary Center, University of Maryland

Background

Overview of NASA Earth Science Program

NASA's Earth Science program is one of four program areas for NASA's Science Mission Directorate (SMD). The purpose of NASA's Earth Science program is to develop a scientific understanding of Earth's system and its response to natural or human-induced changes, and to improve prediction of climate, weather, and natural hazards.¹ The Earth Science Division (ESD) is responsible for coordinating satellite and suborbital missions for long-term global observation of the land surface, biosphere, atmosphere, and

¹ NASA Science Mission Directorate (SMD). Earth Science website available at <<http://science.nasa.gov/earth-science/>>, last accessed on November 3rd, 2015.

oceans.² NASA missions have helped gain new knowledge and create new capabilities that have led to advances in weather forecasting, storm warnings, and the ability to more efficiently manage agricultural and natural resources. Capabilities and discoveries from NASA's program are often later incorporated into National Oceanic and Atmospheric Administration (NOAA) weather satellites or U.S. Geological Survey (USGS) land-imaging satellites.

NASA's Expanding Earth-Observation Responsibilities

Historically, new Earth remote sensing capabilities have been developed in a process whereby NASA develops first-of-a-kind instruments that, once proved, are considered for continuation by NOAA or the USGS.³ NASA has viewed extended-phase operations for Earth science missions as "operational" and therefore the purview of NOAA.⁴ However, recently NASA's Earth science portfolio has expanded to include new responsibilities for the continuation of several previously initiated measurements that were formerly assigned to other agencies, including data continuity and application focused satellite observation programs.⁵ For example, the President's FY16 Budget Request redefines NASA and NOAA Earth-observing satellite responsibilities. Under the proposed framework, NOAA is responsible only for satellite missions that contribute directly to NOAA's ability to issue weather and space weather forecasts and warning to protect life and property. NASA is responsible for all other non-defense Earth-observing satellite missions. The near term impact of this revised framework includes the transfer of responsibility for TSIS-1 (Total and Spectral Solar Irradiance Sensor), Ozone Mapping & Profile Suite (OMPS), JPSS-2 Radiation Budget Instrument (RBI), and future ocean altimetry missions to NASA.⁶

Another example of increased NASA responsibilities is the Sustainable Land Imaging (SLI) program. The purpose of SLI is to provide data continuity to the Landsat missions. Landsat has provided 42 years of space-based medium resolution (15-30 meters) global land-remote sensing measurements. Landsat is a unique resource for those who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research. Under SLI, NASA is responsible for development, launch, and check-out of Landsat 9, along with technology investments and detailed system engineering to design and building a full-capability Landsat 10 satellite.^{7,8} However, in the past, both USGS and NOAA have been responsible for development and operation of Landsat satellites.⁹

² Ibid.

³ National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (2007), at pg. xiii in the preamble.

⁴ Ibid.

⁵ National Academies of Sciences, *Continuity of NASA Earth Observations from Space: A Value Framework* (2015) at pg.1.

⁶ President's Budget Request for NASA Fiscal Year 2016 for the Earth Science's Program at ES 37.

⁷ President's Budget Request for NASA Fiscal Year 2016 at SCMD 5.

⁸ Ibid.

⁹ Under Presidential Directive/NSC-54 (Nov. 16, 1979) NOAA was assigned management responsibility for civil operational land remote sensing activities. However, operational management was not transferred

As stated in a recent National Academies report issued last month:

Starting in fiscal year 2014, the Administration directed NASA to assume responsibility for a suite of climate-relevant observations for the purpose of continuing a multi-decadal data record in ozone profiling, Earth radiation budget, and total solar irradiance. These measurements were to have been implemented by NOAA with the Radiation Budget Instrument (RBI) and the Ozone Mapping and Profiler Suite Limb profiler (OMPS-L) on NOAA's Joint Polar Satellite System 2 (JPSS-2) series, and the Total Solar Irradiance Instrument 2 (TSIS-2) instrument flown separately. NASA received a one-time funding increment of \$40 million in 2014 for these instruments; however, this is only a fraction of the estimated \$200-\$300 million cost for their implementation. [emphasis added] Further, the Senate Appropriations Committee initiated a budget bill (not passed) that directed the development costs and responsibilities for the Deep Space Climate Observatory (DSCOVR) and Jason-3 to be transferred from NOAA to NASA ESD....Pressures on the budget also come from a backlog of decadal survey-recommended missions (NRC, 2012) and an increasing demand for Earth observations to support societal applications (NSTC, 2014).¹⁰

NASA Earth Science Program Budget

Table 1. NASA Science Mission Directorate Budget FY07-FY15¹¹

Budget Authority (\$ in Millions)	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015
NASA Total	16,285	17,309	17,782.4	18,724	18,448	17,770	16,879	17,647	18,010.2
Science Total	4,609.9	4,706.2	4,503.0	4,498	4,920	5,074	4,782	5,151	5,244.7
Earth Sciences	1,198.5	1,280.3	1,379.6	1,439	1,722	1,761	1,659	1,826	1,773
Planetary Sciences	1,215.6	1,247.5	1,325.6	1,364	1,451	1,501	1,275	1,345	1,438
Astrophysics	1,365.0	1,337.5	1,206.2	647	631	648	617	668	685
James Webb Telescope	N/A	N/A	N/A	439	477	519	628	658	645.4
Heliophysics	830.8	830.8	591.6	608	639	645	603	654	662

from NASA to NOAA until 1983. In 1998, the management of the Landsat 4 (and Landsat 5) operations contract was transferred from NOAA to the USGS; operations were continued by the private sector until mid-2001 when Space Imaging (formerly EOSAT) returned the operations contract to the U.S. Government. See [NASA Landsat Science](http://landsat.gsfc.nasa.gov/?p=3178) website at <<http://landsat.gsfc.nasa.gov/?p=3178>>, last accessed on November 3rd, 2015.

¹⁰ National Academies of Sciences, *Continuity of NASA Earth Observations from Space: A Value Framework* (2015) at pg. 7.

¹¹ Note 1: These budget numbers reflect subsequent operating plan changes. Note 2: Both FY2008 and FY2009 appear to omit supplemental appropriations (including ARRA in FY2009, which was substantial: \$400 million for SMD, of which \$325 million for Earth Science).

NASA's Earth Sciences budget is the largest and fastest growing of all SMD budget line items. NASA's Earth Sciences budget has increased approximately 63 percent since 2007.¹²

Table 2. NASA Science Mission Directorate Appropriations, FY2015-FY2016, and Authorizations, FY 2016

Budget Authority (\$ in millions)	FY2015 Enacted	FY2016 Requested	FY2016 House Approp.	FY2016 Senate Approp.	FY 2016 H.R.2039 Authorization	FY 2016 H.R. 2039 Authorization
NASA Total	18,010.2	18,529.1	18,529	18,290	18,529	18,010
Science Total	5,244.7	5,288.6	5,238	5,295	4,952	4,679
Earth Sciences	1,773	1,947	1,683	1,932	1,450	1,199
Planetary Science	1,438	1,361	1,557	1,321	1,500	1,500
Astrophysics	685	709	736	731	731	709
JWST	645	620	620	620	620	620
Heliophysics	662	651	642	650	651	651

NASA proposes to spend about \$1.947 billion on Earth Sciences in Fiscal Year (FY) 2016, an increase of about \$174 million, or about 10 percent, from FY 2015.¹³

NASA Earth Science and Public-Private Partnerships

Public-Private partnerships "generally [are] recognized [to exist] wherever there is a contractual relationship between the public sector and a private sector company designed to deliver a project or service that traditionally is carried out by the public sector."¹⁴ In practice, public-private partnerships can take a variety of forms.¹⁵ Within the context of public-private partnerships for the production and delivery of satellite remote sensing data for scientific research, such forms could include redistributor-end user agreements and "anchor tenant" relationships in which the public sector guarantees that it will be a customer of commercial remote sensing enterprises.¹⁶

NASA's Earth observation program is the largest U.S. government civil remote sensing effort and largest civil remote sensing effort of any nation in the world. NASA currently operates 26 Earth observation satellites, with 12 currently under development.¹⁷ NASA has partnerships with both government and non-government user-communities, domestic and international, to access NASA data provided by these satellites. It has a number of

¹² In FY07, NASA's Earth Science program was appropriated about \$1.198 billion. In 2015, the President's FY 16 Budget Request for NASA's Earth Science program is about \$1.947 billion, a 62.5% increase over FY 2008 appropriation. See [NASA's Historical Budgets](#) on NASA's webpage available at <<http://www.nasa.gov/news/budget/index.html>>, last accessed on November 3rd, 2105.

¹³ President's Budget Request for NASA Fiscal Year 2016 for the Earth Sciences.

¹⁴ Diane Howard, "Achieving a Level Playing Field in Space-Related Public-Private Partnerships: Can Sovereign Immunity Upset the Balance?" 73 J. Air L. & Com. 723 (2008)

¹⁵ *Ibid.*

¹⁶ National Research Council, *Toward New Partnerships in Remote Sensing* (2002) at pg.2.

¹⁷ NASA Science Mission Directorate (SMD), Earth Science, Missions webpage available at <http://science.nasa.gov/earth-science/>, last accessed on November 3rd, 2015.

public-private partnerships on subjects such as data analytics, data visualization, and geospatial products.¹⁸ However, none of NASA's Earth observation satellites, either in operation or under development, are public-private partnerships. NASA does have a program in place to procure commercial satellite Earth observation data under the 1998 Science Data Buy Program, but the program has not been used by NASA for over a decade (discussed in more detail below).

Examples of Government Acquisition of Earth Observation Data through Public-Private Partnerships

TerraSAR-X: TerraSAR-X is a radar Earth observation satellite that was funded jointly by government and industry and launched in 2007. The German space agency, DLR, placed the satellite contract, provided about 80 percent of the financing, and coordinates the scientific use of the satellite's Earth observation data. The remaining 20 percent of the funding was contributed by a company, Astrium, which built the satellite and markets the satellite data. This was first public-private partnership in the German Earth observation space sector. Prior to TerraSAR-X, remote-sensing and climate research satellites in Germany were funded entirely with public money. TerraSAR-X was proven as a successful public-private partnership model and was followed on in 2010 by TanDEM-X, a second almost identical spacecraft to TerraSAR-X.¹⁹

RADARSAT-2: Launched in December 2007, Canada's next-generation commercial radar satellite offers powerful technical advancements that enhance marine surveillance, ice monitoring, disaster management, environmental monitoring, resource management, and mapping in Canada and around the world. This project represents a public-private partnership between government and industry. MacDonald, Dettwiler and Associates Ltd. (MDA) owns and operates the satellite and ground segment. The Canadian Space Agency (CSA) helped fund the construction and launch of the satellite and recovers this investment through the supply of RADARSAT-2 data to the Government of Canada during the lifetime of the mission.²⁰

Worldview: DigitalGlobe is an American commercial vendor of space imagery and geospatial content, and operator of civilian remote sensing spacecraft. It builds and operates a number of spacecraft, including Worldview-1, Worldview-2, and Worldview-3. Worldview-3 is the commercial remote sensing industry's first multi-payload, super-spectral, high-resolution commercial satellite and the most powerful commercial remote

¹⁸ NASA Report, *Public-Private Partnerships for Space Capability Development, Driving Economic Growth and NASA's Mission* (April 2014), available online at <https://www.nasa.gov/sites/default/files/files/NASA_Partnership_Report_LR_20140429.pdf>, last accessed on November 3rd, 2015.

¹⁹ German Aerospace Center information sheet on TerraSAR-X, "TerraSAR-X – First Satellite Funded by Public and Private Sector," available at <http://www.dlr.de/en/Portaldata/28/Resources/dokumente/re/TerraSAR-X_PPP_engl.pdf>, last accessed on November 3rd, 2015.

²⁰ Canadian Space Agency webpage, Activities Sectors, *RADARSAT-2*, available at <<http://www.asc-csa.gc.ca/eng/satellites/radarsat2/>>, last accessed on November 3rd, 2015.

sensing satellite in-orbit.²¹ DigitalGlobe has a public-private partnership through contracts with the National Geospatial Agency. The U.S. Government acts as an anchor tenant for DigitalGlobe, providing sufficient assurance of future revenues for the company to finance, build, own, and operate its commercial satellites. In return, DigitalGlobe provides Earth observation remote sensing data, products, and services that support Federal intelligence, military, and civil agency missions.

National Law and Policy Directing Commercial Use of Space

U.S. law and national policy directs NASA to advance the commercial space sector. Pursuant to the National Aeronautics and Space Act, NASA shall “seek and encourage, to the maximum extent possible, the fullest commercial use of space.”²² NASA is also directed “to the extent possible and while satisfying the scientific or educational requirements of the Administration, and where appropriate, of other Federal agencies and scientific researchers, acquire, where cost-effective, space based and airborne Earth remote sensing data, services, distribution, and applications from a commercial provider.”²³ NASA is required to “develop a sustained relationship with the United States commercial remote sensing industry and, consistent with applicable policies and law, to the maximum practicable, rely on their services.”²⁴

A principle of United States National Space Policy is that “the United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship.”²⁵

The July 2014 National Plan for Civil Earth Observations, states the following policy:²⁶

Federal agencies will identify and pursue cost-effective commercial solutions to encourage private-sector innovation while preserving the public-good nature of Earth observations. U.S. agencies will consider a variety of options for ownership, management, and utilization of Earth observation systems and data, including managed services (Government-Owned/Government-Operated, Government-Owned/Contractor-Operated, or Contractor-Owned/Contractor-Operated), commercially hosted payloads, commercial launch, commercial data buys, and commercial data management. In developing such options, agencies will preserve the principles of full and open data sharing, competitive sourcing, and best

²¹ Digital Globe, WorldView-3 Datasheet, available at < https://dg-cms-uploads-production.s3.amazonaws.com/uploads/document/file/95/DG_WorldView3_DS_forWeb_0.pdf>, last accessed on November 3rd, 2015.

²² 51 USC § 20112(a)(4)

²³ 51 USC §50115(a)

²⁴ 51 U.S.C. §60302

²⁵ White House, U.S. National Space Policy (June 28, 2010)

²⁶ Executive Office of the President, Office of Science and Technology Policy, National Plan for Civil Earth Observations, July 2014, p. 26.

value in return for public investments within legal and financial constraints.

The 2015 National Space Weather Action Plan, as proposed by the Administration, directs Federal agencies to consider commercial solutions to sustain current operational satellite observing capabilities and recognizes that increased access to commercial space-weather observational infrastructure is of mutual benefit to the United States and its partners.²⁷

1998 Science Data Buy Program

The passage of the Commercial Space Act of 1998 called on NASA to acquire, when cost-effective, space-based and airborne Earth remote sensing data, services, distribution, and applications from commercial providers.²⁸ Congress appropriated \$50 million in FY1997 to procure a mix of products and services, and NASA proceeded to implement this activity through the Commercial Remote Sensing Program (CRSP) office at the NASA Stennis Space Center in Mississippi.²⁹ Under the aegis of an experimental Science Data Purchase Program (SDB), scientists received data obtained from commercial providers in support of NASA's Earth Sciences research programs. However, NASA has not requested and Congress did not appropriate additional funding to continue the program in subsequent fiscal years.³⁰

According to the RAND Corporation report from 2000, "In terms of commercial response and quality of products and services, the SDB has been an experimental success in meeting its requirements—some observers were initially skeptical that industry could or would be able to respond in a useful way. However, NASA has not requested and Congress has not allocated any additional funds for the program to continue. NASA has said that it will purchase science data from commercial sources, rather than build new satellites, when these data sources meet Earth Science Enterprise science requirements and are cost effective."³¹

National Research Council Reports

NASA relies on the science community to identify and prioritize leading-edge scientific questions and the observations required to answer them. One principal means by which NASA's Science Mission Directorate engages the science community in this task is through the National Research Council (NRC). The NRC conducts studies that provide a science community consensus on key questions posed by NASA and other U.S. Government agencies. The broadest of these studies in NASA's areas of research are

²⁷ White House, [National Space Weather Action Plan](#) (October 2015)

²⁸ P.L. 105-303, Sec. 107 (Oct. 28th, 1998)

²⁹ Scott Pace, David Frelinger, Beth Lachman, Arthur Brooks, and Mark Gabriele (2000). *The Earth Below: Purchasing Science Data and the Role of Public-Private Partnerships*. DB-316-NASA/OSTP Science and Technology Policy Institute, p. vii.

³⁰ Congress did, however, under the NASA Authorization Act of 2000, Sec. 125, authorize for fiscal years 2001 and 2002 \$25,000,000 for the Commercial Remote Sensing Program for commercial data purchases.

³¹ Ibid.

decadal surveys. As the name implies, NASA and its partners ask the NRC once each decade to look out ten or more years into the future and prioritize research areas, observations, and notional missions to make those observations. The NRC completed its first decadal survey for Earth Science, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* in January 2007 at the request of NASA, NOAA, and USGS. The next Earth science decadal survey is scheduled for 2017.

2007 Earth Science Decadal

The 2007 NRC decadal survey of Earth Science, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*, found that:

“An emerging source of data is the commercial sector. In the past, a program of Earth observations was associated almost exclusively with government-managed or government-sponsored projects. Today, commercial sources of Earth information are rapidly increasing in availability and scope. Commercial satellite systems are now reliable sources of high-resolution Earth imagery, and commercial remote-sensing companies have greatly expanded their offerings. An important example is evident in the emerging Internet geospatial browsers and Web portals, best exemplified by Google Earth and Microsoft Virtual Earth. The new technologies increase dramatically the ability to communicate Earth information to consumers, to share data and information among diverse groups, and to receive feedback from the end users of Earth information. Much of this capability is available for free. A long-term plan for Earth observations and information needs to account for the new sources; they promise to reduce the cost of Earth observation and to introduce new and different ways of looking at Earth.

In reviewing the progress of commercial data providers in obtaining Earth observations and their potential applicability to the decadal plan, the committee sought input on providers of data from both space-based and airborne sources. The detailed and thoughtful responses of two groups indicated a clear expectation for rapidly evolving capabilities over the next decade, including imagery with increasingly fine spatial resolution and substantial improvements in geolocation accuracy. Prices are expected to drop as sources proliferate, and enhanced spectral capability is anticipated, with the possibility that hyperspectral data could become available from commercial sources. Constellations of imaging satellites, designed to reduce intervals between observations, are envisioned. Radar imagery would become widely available, with highly accurate global digital elevation models constituting one product. Much of the demand for such imagery will come from rapidly emerging consumer geospatial Internet applications, but the scientific community should also be able to take advantage of these data sets to complement those obtained with other observing systems.”³²

³² National Research Council, *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (2007), p. 70.

Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research (2002)

In 2002, the NRC published *Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research*.³³ This report identified several approaches to public-private partnerships and other commercial involvement in Earth science. It also reviewed lessons learned from the commercial data purchase program and the SeaWiFS instrument. It made a number of recommendations, including:

- The government partner in a public-private partnership should negotiate in its contract for open scientific distribution and reuse of data obtained under the partnership.
- NASA should permit any academic scientist to compete for data under the Science Data Buy or successor programs.
- Existing remote sensing data series—for example, the Landsat series—within current or anticipated public-private partnerships should be maintained to provide comparable data for scientific research over time. Support should also be made available for research in either the scientific community or the private sector or both on how to generate seamless transitions from one data source to another as new sensors replace past or current sensors.
- Data produced by the private sector in a public-private partnership should be archived for subsequent redistribution to scientists and for creating long time series of data. The government partner should negotiate for permission to do this.
- Public-private partnerships to acquire data for scientific research should ensure that the partnership agreement specifies who has responsibility for calibrating and validating the data, what the scope of the calibration and validation processes is, and what resources (financial, technical, and personnel) will be made available for these purposes.
- In the process of negotiating a public-private sector data partnership, the parties should agree to use commonly accepted standards for metadata, data formats, and data portability.
- The government should facilitate direct communication between members of the scientific community and the private sector, including communication during the early stages of planning for public-private remote sensing programs.
- Representatives of government agencies and commercial firms involved in public-private partnerships, together with scientists who use the data in these programs, should define performance measures at the time the public-private partnership is established. These performance measures should be taken into account in formal program evaluations.

³³ National Research Council, *Toward New Partnerships In Remote Sensing: Government, the Private Sector, and Earth Science Research* (2002).

- Public-private partnerships for producing scientific data should practice realistic cost accounting, making all the costs of the partnership transparent and open to negotiation.

Other Agency Approaches to Commercial Public-Private Partnerships

National Geospatial Agency

In October 2015, the National Geospatial-Intelligence Agency (NGA) released a *Commercial GEOINT Strategy*. According to the NGA, “the remote-sensing industry’s evolving global coverage, rapid revisit rates, diverse spectral content, aggregation of open source venues, and growing analytical capabilities will allow NGA to embrace emergent commercial capabilities with the same dynamism that they embraced National Technical Means decades ago.”³⁴ This strategy recognizes two realities that are in dynamic tensions: (1) real innovation is fueled by diversity, and (2) fiscal resources have become more constrained and will remain so.³⁵ NGA’s strategy articulates both customer-focused objectives and a set of implementation imperatives that guide the actions necessary to achieve these objectives. Among these are to explore, experiment, and evaluate commercial data and products, acquire mission relevant commercial capabilities, and adopt and institutionalize commercial capabilities as a core component of their mission.³⁶ The strategy also lays out key milestones with timelines, objectives, and outcomes sought.

National Oceanic and Atmospheric Administration

In September 2015, the National Oceanic and Atmospheric Administration (NOAA) released a draft commercial space policy for review. According to NOAA, “The policy seeks to establish broad principles for the use of commercial space-based approaches for NOAA’s observational requirements, and to potentially open a pathway for new industry to join the space-based Earth observation process.”³⁷ Public comments on this draft policy were due on October 1st, 2015, and NOAA is currently in the process of reviewing comments and preparing a final policy.

Issues

In light of NASA’s increasing responsibilities for the continuation of several previously initiated measurements that were formerly assigned to other agencies, how can NASA leverage public-private partnerships to maximize its existing funding levels to satisfy its primary Earth science mission?

³⁴ National Geospatial-Intelligence Agency (NGA), *Commercial Geoint Strategy*, October 2015.

³⁵ Ibid.

³⁶ Ibid.

³⁷ NOAA press released on release of draft commercial space policy, posted online at NOAA’s Office of Space Commercialization website (September 1, 2015), available at <<http://www.space.commerce.gov/noaa-releases-draft-commercial-space-policy/>>, last accessed on November 3rd, 2015.

How have technological advancements impacted the viability of commercial public-private partnerships for the provision of space-based Earth observation data to meet NASA program requirements?

What steps should be taken to initiate constructive dialogue between NASA and the private sector on developing alternatives to NASA procurement of Earth observation satellites?

Is there a viable public-private partnership alternative to the proposed Landsat 9 upgraded rebuild of Landsat 8?

What lessons can be learned from NASA's Scientific Data Purchase (SDP) program?

Chairman BABIN. The Subcommittees on Space and Environment will come to order.

Without objection, the Chair is authorized to declare recesses of the Subcommittee at any time.

And welcome to today's hearing titled "Exploring Commercial Opportunities to Maximize Earth Science Investments." I recognize myself for five minutes for an opening statement.

Good morning. I would like to welcome everyone to our hearing today, and I want to thank our witnesses for taking time to appear before our Committee. Today's hearing will explore opportunities for NASA to acquire Earth observation data through public-private partnerships, including commercial capabilities.

NASA's Earth Science is the largest and fastest growing of all Science Mission Directorate programs. In the last eight years, the Earth Science Division funding has increased by more than 63 percent. One reason for these budgetary increases is that NASA's Earth science portfolio has expanded to include new responsibilities for the continuation of measurements that were formerly assigned to other agencies, including data continuity and application-focused satellite observation programs. For example, the President's fiscal year 2016 budget request redefines NASA and NOAA Earth-observing satellite responsibilities. Under the new framework, NOAA is responsible only for satellite missions that contribute directly to NOAA's ability to issue weather and space weather forecasts while NASA is responsible for all other nondefense Earth-observing satellite missions.

The near-term impact of this revised framework includes the transfer of responsibility for TSIS-1, the Total and Spectral Solar Irradiance Sensor, Ozone Mapping & Profile Suite (OMPS), and JPSS-2 Radiation Budget Instrument, or RBI, and future ocean altimetry missions to NASA.

Another example of increased NASA responsibilities is the Sustainable Land Imaging, or SLI program. In the past both USGS and NOAA have been responsible for development and operation of Landsat satellites. But now, NASA is responsible for three mission and development activities, including initiation of Landsat 9, along with a fourth activity to design and build a full-capability Landsat 10 satellite.

Given our constrained budget environment and NASA's new responsibilities, public-private partnerships may offer an opportunity to lower costs and improve Earth observation data while fulfilling science community requirements, including data continuity.

Over the past decade, the United States private space-based remote sensing sector has made significant improvements in technology, products, and services. Leveraging commercial off-the-shelf technology, borrowing ideas from the information technology community, and developing innovative low-cost solutions with high performance outcomes, the private sector is demonstrating new capabilities that could be used to address many of NASA's earth observation data needs.

In the past, Earth observations were associated almost exclusively with government-managed or government-sponsored projects. Today, commercial sources of Earth information are rapidly increasing in availability and scope. Commercial satellite systems are

now reliable sources of high-resolution Earth imagery, and commercial remote-sensing companies have greatly expanded their offerings.

Technology is also rapidly changing. For certain types of missions, solutions can be built that are much smaller in size, much lower in weight, require much less power, and offer even greater data collection capabilities at costs much, much lower than the current systems.

U.S. law and national policy directs NASA to advance the commercial space sector. Pursuant to the National Aeronautics and Space Act, NASA shall “seek and encourage, to the maximum extent possible, the fullest commercial use of space.” NASA is also directed “to the extent possible and while satisfying the scientific or educational requirements of the Administration, and where appropriate, of other federal agencies and scientific researchers, acquire, where cost-effective, space based and airborne Earth remote sensing data, services, distribution, and applications from a commercial provider.”

A principle of the Administration’s United States National Space Policy is that “the United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship.” Both the 2014 National Plan for Civil Earth Observations and the 2015 National Space Weather Action Plan, as proposed by the Administration, direct federal agencies to identify and pursue commercial solutions.

Given the great potential for public-private partnerships, NASA is unfortunately doing very little. NASA’s Earth observation program is the largest U.S. government civil remote sensing effort and perhaps the largest civil remote sensing effort in the world. NASA currently operates 26 Earth observation satellites, with 12 under development. However, none of NASA’s Earth observation satellites, either in operation or under development, are public-private partnerships. NASA does have a program in place to procure commercial satellite Earth observation data under the 1998 Science Data Buy Program. But, the program has not been used by NASA for over a decade.

It is time for NASA to initiate constructive dialogue with the private sector to assess the viability of public-private partnerships for the provision of space-based Earth observation data to meet NASA program requirements. Our Nation cannot afford to simply ignore the great potential of public-private partnerships to lower costs and improve the quality of earth observation data.

There are many important issues to be discussed at today’s hearing, and I look forward to hearing the testimony of our distinguished witnesses.

[The prepared statement of Chairman Babin follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
CHAIRMAN BRIAN BABIN

Good morning. I would like to welcome everyone to our hearing today and I want to thank our witnesses for taking time to appear before the Committee.

Today's hearing will explore opportunities for NASA to acquire Earth observation data through public-private partnerships, including commercial capabilities.

NASA's Earth Science is the largest and fastest growing of all Science Mission Directorate programs. In the last eight years, the Earth Science Division funding has increased by more than 63 percent.

One reason for these budgetary increases is that NASA's Earth science portfolio has expanded to include new responsibilities for the continuation of measurements that were formerly assigned to other agencies, including data continuity and application focused satellite observation programs.

For example, the President's FY16 Budget Request redefines NASA and NOAA Earth-observing satellite responsibilities. Under the new framework, NOAA is responsible only for satellite missions that contribute directly to NOAA's ability to issue weather and space weather forecasts while NASA is responsible for all other nondefense Earth-observing satellite missions. The near term impact of this revised framework includes the transfer of responsibility for TSIS-1 [pronounced Tee-Sis] (Total and Spectral Solar Irradiance Sensor), Ozone Mapping & Profile Suite (OMPS), JPSS-2 Radiation Budget Instrument (RBI), and future ocean altimetry missions to NASA.

Another example of increased NASA responsibilities is the Sustainable Land Imaging (SLI) program. In the past both USGS and NOAA have been responsible for development and operation of Landsat satellites. But now, NASA is responsible for three mission and development activities, including initiation of Landsat 9, along with a fourth activity to design and build a full-capability Landsat 10 satellite.

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Technology is also changing rapidly. For certain types of missions, solutions can be built that are much smaller in size, much lower in weight, require much less power, and offer even greater data collection capabilities—at costs much, much lower than the current systems.

U.S. law and national policy directs NASA to advance the commercial space sector. Pursuant to the National Aeronautics and Space Act, NASA shall “seek and encourage, to the maximum extent possible, the fullest commercial use of space.” NASA is also directed “to the extent possible and while satisfying the scientific or educational requirements of the Administration, and where appropriate, of other Federal agencies and scientific researchers, acquire, where cost-effective, space based and airborne Earth remote sensing data, services, distribution, and applications from a commercial provider.”

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It is time for NASA to initiate constructive dialogue with the private sector to assess the viability of public-private partnerships for the provision of space-based

Earth observation data to meet NASA program requirements. Our nation cannot afford to simply ignore the great potential of public-private partnerships to lower costs and improve the quality of earth observation data.

There are many important issues to be discussed at today's hearing. I look forward to hearing the testimony of our [distinguished] witnesses.

Chairman BABIN. I now recognize the Ranking Member, the gentlewoman from Maryland, for an opening statement.

Ms. EDWARDS. Thank you very much, and good morning and welcome to our distinguished panel of experts.

I want to start by thanking the Chairmen Babin and Bridenstine for calling this hearing on "Exploring Commercial Opportunities to Maximize Earth Science Investments." I also want to thank in advance our Ranking Member on the Environment Subcommittee, Ms. Bonamici, for sitting in the chair when I slip away in just a few minutes, so I appreciate that.

Earth observations support a myriad of applications to meet critical national needs, whether they be related to national security, weather forecasting, agricultural production, land use management, energy production, or protecting human health. Earth observations also support the scientific research and modeling that we hope can someday provide us with a comprehensive understanding of the Earth and its response to natural and human-induced changes.

The collection of Earth observations data has been enabled by sustained federal investments, investments that I hope we will continue to sustain even in the midst of budgetary constraints. Those investments have enabled the development of a robust, value-added industry dedicated to turning Earth observations data into usable information that can benefit broad sectors of our economy. Then too, federal investments in the underlying Earth observations technologies and systems have resulted in capabilities that have enabled a growing commercial remote sensing industry to emerge.

So it makes sense to continuously look for new ways in which we can improve our ability to carry out Earth observations and maximize our Earth Science investments.

Today, we will explore the extent to which NASA might be able to leverage potential public-private partnerships to carry out its Earth Science research and support the applied uses of that research.

Truth be told, NASA has always had prior experience in purchasing commercial Earth observation data, and indeed, makes great use of the private sector. That was my personal experience, having started out at Goddard Space Flight Center working on Landsat but not working for NASA but working for one of its contractors, Lockheed. And so we've made great use of the private sector and its innovation and creativity over many years. This is nothing new. In fact, in the late 1990s and early 2000s, NASA initiated public-private partnerships for Earth science research including one for collecting ocean color data, called SeaWiFS. The results from those early projects demonstrated potential opportunities as well as challenges associated with such partnerships.

The complexities associated with such arrangements were noted in a number of studies by the National Academies of Sciences. For example, at least one of those studies noted that the intersection of scientific and commercial interests in public-private partnerships

can pose significant challenges in attempting to meet the disparate requirements of stakeholders. This is because scientists value the free and open exchange of scientific data; the precise calibration, validation, and verification of satellite data to ensure accuracy; and long-term stewardship of data for future use and future research. However, that may not always be consistent with a company's business goals and models.

In addition, it's clear that intellectual property issues related to licensing will need to be addressed, as well as issues related to data management, data continuity, and calibration if effective partnerships are to be sustained.

So today, I am looking forward to hearing whether, in light of the potential new commercial capabilities in Earth observation, there are productive ways that commercial systems can complement NASA's Earth observation data collection through the use of public-private partnerships, and if so, what mechanisms should NASA use to determine the circumstances under which public-private partnerships can effectively support the agency's Earth science research and applications, and how should those partnerships be evaluated? How can Congress ensure that potential public-private partnerships do not inadvertently restrict and constrain research in an effort to generate revenue for the companies? And, are enacted policies and authorities that enabled the advent of commercial remote sensing adequate to address the future needs of both the federal government and the growing commercial remote sensing industry?

Well, it's clear that there are many issues that need to be addressed, and we certainly are not going to be able to do any more than begin our examination on this important topic today. This can be a productive area for future hearings of the Committee, and I hope we will continue oversight of this area.

I would also note that the National Academies' upcoming Decadal Survey for Earth Science and Applications is also likely to address a number of these same issues, and I look forward to hearing the results of that survey when it's done.

Finally, I would be remiss if I didn't note that we have long had existing productive public-private partnerships in Earth observations, and so for the many contractors and suppliers who have built a formidable array of both civilian and national security Earth observations spacecraft and ground systems for NASA, NOAA, and other parts of the government, you are testimony to the long-standing commitment our government has had to making use of the skills and capabilities of the private sector, and they are many. I have every confidence that these type partnerships will continue to be productive both today in the years to come.

And with that, I want to thank our witnesses today and I especially want to thank our two home witnesses, Dr. Samuel Goward, who's the Emeritus Professor of Geography at the University of Maryland at College Park, and Dr. Antonio Busalacchi, Professor and Director of the Earth Systems Science Interdisciplinary Center, University of Maryland as well, and I am proud to say, you're great Marylanders and you come from great Maryland institutions, and welcome to today's panel.

Thank you.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
RANKING MEMBER DONNA F. EDWARDS

Good morning, and welcome to our distinguished panel of experts.

I want to start by thanking the Chairmen Babin and Bridenstine for calling this hearing on "Exploring Commercial Opportunities to Maximize Earth Science Investments."

Earth observations support a myriad of applications to meet critical national needs, whether they be related to national security, weather forecasting, agricultural production, land use management, energy production, or protecting human health. Earth observations also support the scientific research and modeling that we hope can someday provide us with a comprehensive understanding of the Earth and its response to natural and human-induced changes.

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Those investments have enabled the development of a robust "value-added" industry dedicated to turning Earth observations data into usable information that can benefit broad sectors of our economy. Then too, federal investments in the underlying Earth observations technologies and systems have resulted in capabilities that have enabled a growing commercial remote sensing industry to emerge.

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Truth be told, NASA has had prior experience in purchasing commercial Earth observation data. In the late 1990s and early 2000s, NASA initiated public-private partnerships for Earth science research including one for collecting ocean color data, called SeaWiFS. The results from those early projects demonstrated potential opportunities as well as challenges associated with such partnerships.

The complexities associated with such arrangements were noted in a number of studies by the National Academies of Sciences. For example, at least one of those studies noted that the intersection of scientific and commercial interests in public-private partnerships can pose significant challenges in attempting to meet the disparate requirements of stakeholders.

This is because scientists value the free and open exchange of scientific data; the precise calibration, validation, and verification of satellite data to ensure accuracy; and long-term stewardship of data for future research. However, that may not always be consistent with companies' business models.

In addition, it is clear that intellectual property issues related to licensing will need to be addressed, as will issues related to data management, data continuity, and calibration if effective partnerships are to be sustained.

So today, I am looking forward to hearing whether, in light of potential new commercial capabilities in Earth observation, there are productive ways that commercial systems can complement NASA's Earth observation data collection through the use of public-private partnerships.

And if so, what mechanisms should NASA use to determine the circumstances under which public-private partnerships can effectively support the agency's Earth science research and applications, and how should those partnerships be evaluated?

How can Congress ensure that potential public-private partnerships do not inadvertently restrict and constrain research in an effort to generate revenue for the companies? And, are enacted policies and authorities that enabled the advent of commercial remote sensing adequate to address the future needs of both the Federal government and the growing commercial remote sensing industry?

Well, it is clear that there are many issues that need to be addressed, and we certainly are not going to be able to do any more than begin our examination of this important topic today. This can be a productive area for future hearings of the Committee, and I hope we will do continued oversight of this area.

I would also note that the National Academies upcoming Decadal Survey for Earth Science and Applications is also likely to address a number of these same issues, and I look forward to hearing the results of the Survey when it is done.

Finally, I would be remiss if I didn't note that we have long had an existing productive public-private partnership in Earth observations.

The many contractors and suppliers who have built a formidable array of both civilian and national security Earth observations spacecraft and ground systems for NASA, NOAA, and other parts of the government are testimony to the long-standing

commitment our government has had to making use of the skills and capabilities of the private sector. I have every confidence that that partnership will continue to be a productive one in the years to come.

With that, I again want to thank our witnesses for being here today, and I look forward to your testimony.

Chairman BABIN. Thank you, Ms. Edwards.

I now recognize the Chair of the Environment Subcommittee, the gentleman from Oklahoma, Mr. Bridenstine, for an opening statement.

Mr. BRIDENSTINE. Well, thank you, Chairman Babin, and thank you for hosting this hearing today. I'm very excited about the panel that's here. I'm very excited about the prospects before our country.

In so many cases, what's happening in space, it is outpacing—the commercial sector is outpacing what the government has been able to do, and that's very exciting for us to figure out how do we take advantage of what commercial industry is doing.

I sit on the Armed Services Committee as well. We've been dealing a lot with the space-based communication architecture. Commercial industry has been providing massive amounts of capacity for our war fighters all over the world, and of course, they've been doing it because we had a need and commercial industry was there to meet that need. They didn't launch satellites because the government asked them to; they launched satellites to make a profit and provide a return for their shareholders. At the end of the day, the Department of Defense said we need that capability, and what's happening now, because of commercial industry, we're getting higher throughput and more capacity than we've ever seen before for our space-based communication architecture, a lot of it provided by commercial that we as a government can take advantage of. So that's an important, I think, analogy to what we're going to talk about today.

I would also say that on the NOAA side, we have private companies that are preparing to launch satellites that can do things like GPS radio occultation and hyperspectral sensing, and of course, Dr. Pace, I read your testimony, and you talked about how these technologies, we've been considering commercializing these technologies for a very long time going back to the 1990s, which I did not know before reading your testimony, but now commercial industry is at a point where we as a government can take advantage of these technologies in ways where we haven't before and improve our ability to predict and forecast weather, which of course is very important to my district. I come from the 1st District of Oklahoma. This year I've already lost one constituent to a tornado. I've lost constituents in previous years, and I will lose constituents again next year. So taking advantage of these capabilities that have been advanced by the private sector in many ways is critically important to us as a government.

I read your testimony, Mr. Schingler, about some of the ways that NASA is already partnering with the private sector. You talked about settlements as a service, and you talked about venture-class launch services through the Launch Services program, ways that we can get things into space more effectively and more cost-effective so that we can take advantage of the great things that are happening in commercial industry today.

And of course, remote sensing, when you talk about the National Geospatial Intelligence Agency, they're taking advantage of the capabilities of the people that are sitting on this panel right now, and they're doing it because they know that the direction you are going, you're going much more rapidly than they can go themselves, and to understand that, the idea that we can get higher-resolution imagery that can provide mensurated coordinates, the idea that we can have more rapid revisit times, and even motion pictures, these are capabilities now that the commercial sector is providing that we as a government absolutely must figure out how to take advantage of. Your capabilities are impressive. We need to learn what you're able to do. We need to figure out as a country as we go forward, you know, there is a lot of talk about what is a global public good, what is a public good. There's a lot of talk about if it is a public good, how do you as a private company protect your proprietary data that you rely on to actually provide a return on investment. These are challenging issues that this panel and other panels are going to have to work through.

I want to be really clear. When it comes to the Earth Sciences Division at NASA, the Science Mission directorate, this is an agency that has been very effective in doing important work on behalf of my constituents. They are teaching us more about the Earth so that we can protect our constituents from weather, and of course, the things that they have done have done just that.

So Chairman Babin, thank you for having this hearing, and to our panelists, thank you for being here. I'm very much looking forward to this testimony.

[The prepared statement of Mr. Bridenstine follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON ENVIRONMENT
CHAIRMAN JIM BRIDENSTINE

Chairman Bridenstine: Good morning. I thank the gentleman from Texas, Dr. Babin, for holding this hearing. Today we are discussing an issue that has been the subject of a number of hearings before the Environment Subcommittee this year: utilizing commercial solutions to satisfy government missions.

My subcommittee has examined how the National Oceanic and Atmospheric Administration, NOAA, could apply commercial space-based data to improve weather forecasting. In similar fashion, today we will explore commercial opportunities to provide NASA with critical earth science data.

As one of NASA's Science Mission Directorates, contributions from Earth Sciences have enhanced our understanding of the Earth. As one example, NASA Earth Science missions have improved our weather forecasts. I represent the State of Oklahoma - I know all too well the dangers posed by severe weather events, and the need to improve our capabilities of predicting storms to protect lives and property.

At NOAA, the opportunity exists for the Agency to partner with the growing commercial weather industry. Such partnerships could greatly reduce the cost of operating large monolithic satellite systems, resulting in lower government spending, greater resiliency, and increased quality of forecasts.

The Environment Subcommittee has heard from a number of private sector companies that have or will soon have the capabilities to provide data to NOAA, and want to partner with the Agency. In an encouraging sign, NOAA has begun to take notice of the emerging industry and has started taking the first steps to incorporating private space-based technologies.

In September of this year, NOAA released a draft commercial space policy, designed to assist the acquisition of future commercial technologies. I look forward to NOAA releasing a final version that incorporates stakeholder concerns and feedback with the draft version. In encourage NOAA to make releasing the final Commercial Space Policy a top priority, along with releasing the necessary next steps such as

NESDIS' accompanying procurement process guide. These documents are essential to forming the basis for how the private sector will interact with NOAA going forward.

I am pleased to see this Committee taking the first steps to look at how NASA can follow a similar trajectory. It is my firm belief the government ought not do what the private sector can. Our ability to utilize commercial options will minimize government spending and aid mission directives. I am optimistic that a market will materialize for many different space-based technologies, as we have seen time and time again with the Department of Defense's requirements and are beginning to see with NOAA's needs. NASA ought to recognize this pattern and take a good hard look at utilizing these opportunities.

To do this, NASA should take a proactive step to re-establish its commercial earth observation data buy program that has laid dormant for years, establish clear policy supporting and directing the acquisition of commercial data, establish the appropriate protocols to support commercial options, and begin meaningful dialogue with the private sector to assess the usefulness of public-private partnerships to meet its Earth observation data requirements.

With NOAA, we've seen commercial space-based data companies waiting for the Agency to have a finalized framework in place so they can enter into agreements, raise capital, and launch satellites. However, in the case of NASA, there isn't a commercial earth observation data policy in place yet.

I hope this hearing can be used to identify and determine the necessary first steps in that process.

I thank the witnesses for being here today, and look forward to your testimonies. Thank you and I yield.

Chairman BABIN. Thank you, Chairman Bridenstine. I appreciate that.

I now recognize the Ranking Member of the Subcommittee on Environment, the gentlewoman from Oregon, Ms. Bonamici, for an opening statement.

Ms. BONAMICI. Thank you very much, Mr. Chairman, and thank you to all of our witnesses for being here today.

Chairman Bridenstine and I have held a number of thoughtful and engaging hearings examining how NOAA can advance the role of the commercial sector in providing critical weather data to our National Weather Enterprise. We've discussed potential challenges and opportunities with numerous representatives of the weather community, and with Vice Admiral Manson Brown, the Assistant Secretary of Commerce for Environmental Observation and Prediction.

The message has been consistent: there are great opportunities to engage the commercial sector in ways to supplant NOAA's observational mission—supplement NOAA's observational mission, but we must maintain the core policies, namely free and open access to data, that have allowed our scientific community and the American weather industry to drive innovation and economic growth. Our critical weather data must remain reliable and of the highest quality to protect the lives and livelihoods of millions around the world.

In September, NOAA released its draft Commercial Space Policy, which outlines the policies and guidelines for how the agency will engage with the commercial sector. Most importantly, NOAA reaffirms its commitment to adhere to the policy and practice of full, open, and free data exchange as established by current laws and policies to maintain a system of reciprocity for global data. A system of reciprocity that means NOAA receives three times the amount of data it contributes—improving forecasts and reducing costs.

I am pleased that NOAA appears to be on the right path to improve engagement with its commercial partners, and I'm looking forward to reviewing the final policy, which I understand will be released in the coming weeks. NOAA has an operational mission, and their data and information are considered public goods.

NASA serves a research mission with different challenges and opportunities to engage the commercial sector, and as we've discussed today, there have been partnerships going on for quite a long time. So although there may be an opportunity for NASA to adapt some of NOAA's commercial policies, there are certainly important distinctions that require careful consideration.

A common challenge both agencies face is ensuring that data purchased from commercial sources can be shared without significant restrictions. For the most part, the unrestricted access to weather data has been the foundation of the current billion-dollar commercial weather industry, an industry that is the best in the world. It's very likely that data purchased by NASA can be shared in a way to further stimulate future commercial ventures.

At the same time, a gap in data continuity in NASA's Earth observations could have serious and detrimental effects on our research enterprise and our understanding of the climate. Both NOAA and NASA are well aware that existing partnerships with private companies carry risks, such as delays in production, launch failures, and cost overruns. For NOAA, any commercial policy that provides critical observational data for weather predictions must consider these factors, as well as the risk to the lives of millions of people across the country. NASA faces similar challenges when developing its path forward to engage its commercial partners, if not on the same scale.

Mr. Chairman, again I am pleased that we are having this hearing, not only to recognize the positive direction NOAA is taking to engage commercial parties, but to identify common ground for NASA to adopt into its own commercial policies, and I look forward to hearing from our witnesses, and I know they have years of expertise among them. We're fortunate to have them here.

And I yield back the balance of my time. Thank you, Mr. Chairman.

[The prepared statement of Ms. Bonamici follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON OVERSIGHT
MINORITY RANKING MEMBER SUZANNE BONAMICI

Thank you, Mr. Chairman, and thank you to our witnesses for being here today. Chairman Bridenstine and I have held a number of thoughtful and engaging hearings examining how NOAA can advance the role of the commercial sector in providing critical weather data to our national weather enterprise. We have discussed potential challenges and opportunities with numerous representatives of the weather community, and with Vice Admiral Manson Brown, the Assistant Secretary of Commerce for Environmental Observation and Prediction.

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A common challenge both agencies face is ensuring that data purchased from commercial sources can be shared without significant restrictions. For the most part, the unrestricted access to weather data has been the foundation of the current billion dollar commercial weather industry, an industry that is the best in the world. It is very likely that data purchased by NASA can be shared in a way to further stimulate future commercial ventures. At the same time, a gap in data continuity in NASA’s Earth observations could have serious and detrimental effects on our research enterprise and our understanding of the climate.

Both NOAA and NASA are well aware that existing partnerships with private companies carry risks, such as delays in production, launch failures, and cost overruns. For NOAA, any commercial policy that provides critical observational data for weather predictions must consider these factors, as well as the risk to the lives of millions of people across the country. NASA faces similar challenges when developing its path forward to engage its commercial partners, if not on the same scale.

Mr. Chairman, again I am pleased that we are having this hearing, not only to recognize the positive direction NOAA is taking to engage commercial parties, but also to identify common ground for NASA to adopt into its own commercial policies. I look forward to hearing from our witnesses, and I yield back the balance of my time.

Chairman BABIN. Thank you, Ms. Bonamici.

I’d like to now recognize the Ranking Member of the full Committee for a statement, the gentlelady from Texas.

Ms. JOHNSON OF TEXAS. Thank you very much.

Good morning, and welcome to our distinguished panel of witnesses. I am pleased that we have an opportunity to discuss NASA’s Earth Science and Applications program.

As I have said on numerous occasions, NASA is a critical engine of discovery, science, innovation, and inspiration. Earth Science and applications research is a key agency responsibility.

A 2005 study by the National Academies stated that “Decades of investments in research and the present Earth observing system have also improved health, enhanced national security, and spurred economic growth by supplying the business community with critical information.” NASA’s Earth Science and Applications program provides a broad array of benefits and applications across the public and private sectors. For example, after the Deepwater Horizon spill in 2010, NASA’s project allowed response teams to track the movement of the oil into the coastal waterways, and this was critical in assisting in monitoring the impact and recovery of affected areas along the Gulf of Mexico.

Our investment in Earth observations has also spawned successful international cooperation. The Global Precipitation Measurement, or the GPM mission, a cooperative effort by NASA and the Japanese Aerospace Exploration Agency, is advancing our understanding of Earth’s water and energy cycles, improving the forecasting of extreme events that cause natural disasters, and extending current capabilities of using satellite precipitation information

to directly benefit society. Maintaining and enhancing our Earth Science capabilities and investments in the years to come will require that we continuously look for new sources, be they international or from the private sector. Indeed, with growing numbers of American companies launching and operating space-based remote sensing small satellites, this may be an opportune time to assess the private sector's ability to complement NASA's Earth observation systems.

I hope our distinguished panel will provide us with an objective assessment of both the opportunities and challenges associated with leveraging commercial offerings.

With that, again I want to thank our witnesses for being here today, and I look forward to your testimony. I yield back.

[The prepared statement of Ms. Johnson of Texas follows:]

PREPARED STATEMENT OF FULL COMMITTEE
RANKING MEMBER EDDIE BERNICE JOHNSON

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With that, I again want to thank our witnesses for being here today, and I look forward to your testimony. With that, I yield back.

Chairman BABIN. Thank you, Mrs. Johnson.

Now, let me introduce our witnesses. Our first witness today—I want to thank you all for being here. We really appreciate it. The first witness today is Dr. Pace. Testifying first is Dr. Scott Pace, Director of the Space Policy Institute, and Professor of the Practice of International Affairs at the George Washington University. Dr. Pace previously served as Associate Administrator for Program Analysis and Evaluation at NASA, as Assistant Director to Space and Aeronautics in the White House Office of Science and Technology Policy, and as Deputy Director and Acting Director of the

Office of Space Commerce and the Office of the Deputy Secretary of the Department of Commerce. Dr. Pace earned his bachelor of science degree in physics from Harvey Mudd College, master's degrees in aeronautics and astronautics, and technology and policy from the Massachusetts Institute of Technology, and a doctorate in policy analysis from the RAND Graduate School.

And Dr. Scott. Our second witness today is Dr. Walter Scott—Sir Walter Scott, we said a while ago—Founder, Executive Vice President and Chief Technical Officer for DigitalGlobe, the first company to receive a high-resolution commercial remote sensing license from the U.S. government. Dr. Scott has previous experience serving as the Assistant Associate Director of the Physics Department for the Lawrence Livermore National Laboratory and is President of Scott Consulting. Dr. Scott earned a bachelor of arts in applied mathematics from Harvard University and a doctorate and master of science and computer science from the University of California at Berkeley.

Mr. Robbie Schingler is a Co-Founder and the President of PlanetLabs. Mr. Schingler has nine years of NASA experience under his belt helping to build a small spacecraft office at NASA Ames and serving as Capture Manager for the Transiting Exoplanet Survey Satellite, or T-E-S-S, TESS, that will launch in 2017. Robbie has also served as NASA's Open Government Representative to the White House and is Chief of Staff for the Office of the Chief Technologist at NASA. And Mr. Schingler has received his master of business administration from Georgetown University, his master of science in space studies from the International Space University, and his bachelor of science in engineering physics from Santa Clara University. Good to have you.

Testifying fourth is Dr. Samuel Goward, Professor Emeritus at the Department of Geographical Sciences at the University of Maryland, College Park. Dr. Goward has a long history working with remote sensing beginning his career with NASA Goddard Institute for Space Studies. He then worked at NASA Goddard Space Flight Center where he helped build the University of Maryland geography department. Dr. Goward has served as Co-Chair of the USGS National Landsat Archive Advisory Committee and is the recipient of the USGS Powell Award, the highest USGS award bestowed upon non-agency individuals. Dr. Goward earned his bachelor's and master's degrees in geography from Boston University and his Ph.D. in geography from Indiana State University. Thank you for being here.

And Dr. Busalacchi. Our final witness today is Dr. Antonio Busalacchi, Director of the Earth Systems Science Interdisciplinary Center and Professor in the Department of Atmospheric and Oceanic Science at the University of Maryland. Dr. Busalacchi previously served as Chief of the NASA Goddard Laboratory for Hydrospheric Processes. Dr. Busalacchi also has experience as Chair of the Joint Scientific Committee that oversaw the World Climate Research program, and as the Chair of several National Academy of Science and National Research Council Boards and Committees relating to remote sensing. Dr. Busalacchi currently serves as Co-Chair of the National Research Council's Decadal Survey on Earth Science and Applications from Space. Dr. Busalacchi

earned his bachelor's in physics, his master's in oceanography, and his Ph.D. in oceanography from Florida State University.

I now recognize Dr. Pace for five minutes to present his testimony. Dr. Pace, thank you.

**TESTIMONY OF DR. SCOTT PACE,
DIRECTOR OF THE SPACE POLICY INSTITUTE,
GEORGE WASHINGTON UNIVERSITY**

Dr. PACE. Thank you, Mr. Chairman, and thank you for the opportunity, particularly in a joint fashion, to discuss the important topic of how commercial capabilities could be used to the benefit of the Nation's Earth science investments.

I had the privilege of working on Title II of the 1992 Land Remote Sensing Act with Barry Beringer, the former Chief Counsel of the House Committee on Science. In the aftermath of the Cold War, at that time Title II reformed the U.S. commercial remote sensing license process, and removed many commercial regulatory barriers. This reform was successful beyond our somewhat modest expectations, leading to a more dynamic and information-driven global industry.

The idea, as has been noted, of buying data from commercial sources for NASA, is indeed not new. In 1998, I testified to the House Subcommittee on Basic Research on using commercial data sources in NASA's Earth Science Enterprise. At the time, I discussed the need for NASA to consider the needs of other civil agencies in buying commercial data for Earth science needs. The idea was that NASA's capabilities and buying power could be leveraged to support other public missions. New applications of remote sensing data could be demonstrated to accelerate the growth of commercial applications.

Looking back from now, the National Geospatial Intelligence Agency, rather than NASA, became the dominant government purchaser of the U.S. commercial remote sensing data. Information technologies also advanced rapidly so that more computer and sensing power could be packed into smaller packages, and our concerns over access to adequate radiofrequency spectrum for remote sensing also turned out to be somewhat correct. There is in fact increasing pressure on spectrum not so much for remote sensing bandwidth but from competing demands from mobile terrestrial communications.

Rather than a few conventional satellites connected to centralized data management systems, we are seeing dozens of small satellites connecting to highly distributed networks in which even an iPad might be a ground station. And among other changes, sometimes the data files are becoming so massive that moving them to the user becomes less efficient than creating large data cubes that users can query remotely it's truly remarkable how much data's being put together.

Today, NASA's Earth Science Division researchers can propose to purchase commercial data using contractor grant funds when the purchased information is required by or would substantially enhance the research activity. Now, of course, if similar data or information were available in the public domain, there would no point in making that purchase, and some commercial data may already

be available under all government licenses such as those held by NGA, so there are some potential public-private partnership activities already going on.

It's also not news to those here today that budget allocations have been flat or declining in real-dollar terms for NASA and NOAA. If NASA were to have the same buying power that it had in fiscal year 1992 when we did the Land Remote Sensing Act, it would have a budget of about \$24 billion. At the same time, NASA is now being asked to support more Earth science activities than just those of the Decadal Survey. The success of past NASA missions has created ongoing demands for operational yet exquisite scientific data, and this makes it difficult for NASA to fund new starts for Decadal Survey priorities.

For both agencies and companies, it's common to find that each wants to only pay, as we would say, the marginal cost of having a capability rather than the average cost of having a capability. If the dominant market demand is for a public good, then not unreasonably the burden rightly would fall on the government. If the dominant market demand is from private customers, then the burden should be borne by the private sector.

In many cases of civil remote sensing, however, like Landsat, there's a roughly even balance of public and private sector demand, which makes a clear partnership and definitions much more difficult, not easier.

Major elements, I would argue, of NASA's Earth Science program are likely to remain government-led due to the lack of commercial demand for specialized scientific data, that is, customers outside of the government. Commercial providers will likely not soon replace unique platforms such as those on the A train. On the other hand, where NASA needs can be met by commercial data sources, cooperation with other agencies such as NGA can increase the government's buying power, and as has been noted, NASA does have the authorities to do this more extensively.

In acquiring commercial data, NASA should ensure that it gets sufficient rights so that data sets can be shared for scientific non-commercial purposes. It should ensure that as sufficient insight into how the data was generated such as peer review can independently assess conclusions based on those data, and I think some of the other witnesses will likely note that there are a variety of rights that can be bought, and it's not a one-size-fits-all situation.

There should be procurement on-ramps to enable experimentation and large-scale innovation in parallel with current government systems and international partnerships. We can talk about some of those, for example, for Landsat. In the long term, it will be more risky to pursue only traditional acquisitions without a mixed portfolio that includes non-traditional and commercial procurements.

Finally, NASA should continue to be a strong domestic and international advocate of preventing interference with radio spectrum upon which all remote sensing relies. Spectrum protection is and will continue to be challenging due to commercial terrestrial communication demands for more spectrum in the years ahead.

Thank you for your attention and I look forward to any questions.

[The prepared statement of Dr. Pace follows:]

**Hearing of the House Committee on Science, Space, and Technology
Subcommittee on Environment
Subcommittee on Space**

“Exploring Commercial Opportunities to Maximize Earth Science Investments”

Tuesday, November 17, 2015 - 10:00 AM – RHOB 2318

**Testimony of Dr. Scott Pace
Director, Space Policy Institute
Elliott School of International Affairs
The George Washington University**

Thank you, Mr. Chairman, for providing an opportunity to discuss the important topic of how commercial capabilities could be used to benefit the nation’s Earth Science investments.

From 1990 to 1993, I was a civil servant in the U.S. Department of Commerce and worked with the National Space Council on policy guidelines to encourage the growth of commercial space activities. We recognized the many different roles the government might play, not only as a customer and anchor tenant, but also as a regulator and supporter of research and development too risky for the private sector.

I had the privilege of working on Title II of the Land Remote Sensing Policy Act with Barry Beringer, the former chief counsel of the House Committee on Science. In the aftermath of the Cold War, Title II reformed the U.S. commercial remote sensing licensing process and removed regulatory barriers to space-based commercial remote sensing. This reform was successful beyond our somewhat modest expectations, leading to a more dynamic, information-driven global industry.

The idea of buying data from commercial sources for NASA needs is not new. In 1998, I testified to House Subcommittee on Basic Research on “Using Commercial Data Sources in the Earth Science Enterprise” and the development practical applications for remote sensing. At the time, I discussed the need for NASA to actively consider the needs of other civil agencies in the acquisition of commercial data for Earth science needs. The idea was that NASA’s capabilities and buying power could be leveraged to support other public missions such as managing natural resources and responding to natural disasters. New applications of remote sensing data could be demonstrated to benefit the public and accelerate the growth of commercial applications.

The potential for small satellites to match the capabilities of traditional satellites was just emerging. Utilizing technologies developed under the Strategic Defense Initiative, there were conceptual industry designs for a “lightsat” version of Landsat in 1992. The Administration chose however to build a conventional satellite for

Landsat 6 instead. Unfortunately, the satellite failed to reach orbit. Its replacement, Landsat 7 was successfully launched in 1999. The original plans for Landsat 8 were for NASA to purchase data meeting its specifications from a commercially owned and operated satellite system. After evaluating industry proposals, NASA cancelled this approach in 2003 in favor of placing Landsat sensors on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). This was a short-lived effort and the Administration again shifted to conventional satellite procurements, and Landsat 8 was launched in 2013.

Current Conditions and Global Trends

Access to space-based information capabilities and technologies is virtually ubiquitous, and access to space launch services is nearly so. The past decade has witnessed an increasing number of American entrepreneurial firms seeking non-traditional markets. The growth of Big Data and location-based services applications has created significant new demand for geospatial data. The fusion of data from multiple sources will allow motivated nations, multinational companies, and even small groups or individuals to improve their access to previously unavailable information that can have potential strategic implications.

The National Geospatial-Intelligence Agency (NGA), rather than NASA, became the dominant government purchaser of U.S. commercial remote sensing data. Information technologies have continued to advance rapidly so that more computer and sensing power can be packed into smaller packages. After almost twenty years, these information technology advances have led to small satellites emerging as the latest “overnight success.” Concerns over access to adequate radiofrequency spectrum for remote sensing turned out to be partially correct. There is pressure on spectrum, but not so much from bandwidth demands for remote sensing but from competing demands by mobile terrestrial communications.

Market demands, deployed satellite technologies, and ground processing practices have all changed in the last decade. Rather than a few conventional satellites connecting to centralized data management systems, we are seeing potentially dozens of small satellites connecting to highly distributed networks in which even an iPad might be a ground station. Data processing is accomplished in highly diverse ways depending on specific applications rather than being driven by the space segment. In some cases, data files are so massive that moving them to the user is less efficient than creating a large “data cube” that users can query remotely. In other cases, targeted data are delivered to a user in the field to for remote processing.

The small satellite technologies and a rapidly evolving Internet have created major challenges to the regulatory structure created in the 1990s for commercial remote sensing. While perhaps more appropriate for a separate hearing, the ability of NASA to benefit from an innovative U.S. commercial remote sensing industry depends on an efficient and effective licensing and oversight process at the U.S. Department of

Commerce. That process is hard pressed to keep up with the changes occurring in the industry today.

The significance of private funding and development of new capabilities is coupled with the reality of globalization. Not only are modern space capabilities becoming ubiquitous but private funding also means that new and unexpected capabilities may be developed elsewhere in the world. To date, it has been to the advantage of the United States that innovative space activities have been concentrated in U.S. companies. This advantage is predicated on a timely and responsive domestic regulatory process and favorable economic conditions, but these cannot be assumed to be a given.

Another challenge that has become more severe in recent decades has been the increasing pressure on non-defense discretionary budgets. It is not news to those here today that budget allocations have been flat or declining in real dollar terms. If NASA were to have the same buying power today that it had in Fiscal Year 1992, it would have a budget of about \$24 billion dollars. At the same time, NASA is supporting more Earth science activities than just those of the decadal survey. In some cases, this is to support critical NOAA weather satellites or maintain the invaluable continuity of Landsat data. In other cases, the success of NASA missions in the A-train has created on-going demands for “operational” yet “exquisite” scientific data. This makes it difficult for NASA to fund new starts for decadal survey priorities.

Competing Public and Private Interests

In using tax dollars to acquire, process, and analyze data about the Earth, the United States seeks to serve multiple national interests. These include national security, economic competitiveness, and in the case of NASA, science and exploration. As discretionary budgets tighten and private sector capabilities grow, it is particularly appropriate to look at agency “make or buy” decisions. That is, in what situations is it best for an agency to develop, build, and operate its own space system and in what situations is it better for it to buy data licenses and value-added information products from a private provider?

Government is not a business, but business approaches can be helpful in thinking about the efficient use of public resources. A first concern is that agencies should not compete with the private sector unless there are compelling public safety or national security reasons. A second concern is that the unique needs of the public and private sector need to be understood.

One of my former students, Dr. Mariel Borowitz, is now an assistant professor at George Tech. She is writing a book on the international spread of open data policies for remote sensing archives, despite the attempts by many governments to monetize their databases through user fees. The United States tried to change user fees for Landsat data for many years with little success. With the Internet enabling

virtually zero cost distribution, the United States dropped user fees for Landsat and other civil government data. Not surprising, this led to a dramatic increase in the use of Landsat data by businesses and universities. More importantly, it led to commercial and scientific results that have benefited the public through new information products and services.

The general policy principle for data sales should be simple. If data products are created by private funds, the private entity should own all the rights and can license them in response to markets. If public funds are used, then the data products should be provided at marginal cost – which is effectively free with today’s IT systems. If a mixture of government and private funds are involved, the data rights need to be negotiated upfront between government and industry as a competitive consideration for partnership. If civil data are provided by a foreign system, the U.S. government should seek to get free data access in a manner reciprocal to how it provides similar data to the international community.

As I mentioned earlier, NGA is an anchor customer for the commercial remote sensing industry. NGA released a “Commercial GEOINT Strategy” in October that described agency intentions to shift its emphasis from the acquisition of raw data to analytical and contextual products. The growth of satellite constellations that can provide near persistent observation with increasingly sophisticated geospatial business applications means NGA may be able to meet the needs of its customer more quickly and at less expense. While defense needs and commercial needs are different and one cannot be substitute for the other, there are growing functional overlaps between the two that make for cooperative opportunities.

Like computer software and games, data products can come in multiple versions that can command different prices. For example, the most capable software may command a high price while less capable or older versions are provided for free. Unprocessed or lightly processed data can be made freely available for higher processing and value-added products may require payments. One can think of freely available Landsat data as not only providing a public good benefit for science but also fostering upgrades to more specialized, and expensive, commercial sources.

Talking about “data purchases” is often misleading, as what actually occurs is the purchase of a license to use the data. Similarly, when you buy a computer program, you are buying a software license, not the program itself. In a recent paper, Dr. Borowitz made the point that there are a wide variety of possible licensing arrangements.¹ These include providing license-free raw and processed data, as well as fee-based raw data and processed data. Depending on the specific data and

¹ Borowitz, Mariel. “Examining Economic Models for Remote Sensing Satellite Data,” paper presented to the International Astronautical Congress Symposium E6.1 *Case Studies and Prizes in Commercial Space* September 13, 2015 Jerusalem, Israel

who the potential customers are, providers will seek to spread their fixed costs over a wide base while recovering their variable costs. Data licenses can be open or restricted, with restrictions at many different scales, from individuals to companies, to countries. There is also a time-dependence to the value of the data licensee with the most commercially valuable data being the freshest, in near real-time, while science data (e.g. climate records) can be older with no loss in value.

One of the differences between data and value-added products is that the former are more like public goods and the latter are more like commodities. In general, government should provide data while industry provides value-added products, if there are also non-government customers. The last condition is perhaps the most significant for NASA missions. Decadal science priorities by their nature represent information that does not exist and for which there is no private demand at current technical and market conditions.

NASA Relevance

In principle, NASA has been open to buying (licensing) commercial data for a long time. The idea of promoting greater reliance on commercial goods and services is an old one, going back at least to the 1991 U.S. Commercial Space Policy Guidelines. Data purchases were part of the funded Space Act Agreements for commercial cargo support to the International Space Station. Commercial data purchases were considered for developing lunar landers in the Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) effort using unfunded Space Act Agreements.

Today, NASA Earth Science Division researchers can propose to purchase commercial data using contract or grant funds when the purchased information "is required by, or would substantially enhance, their research activity." As a practical matter, if similar data or information were available in the public domain there would be no point in making the purchase. Some commercial data may already be available under all-government licenses such as those held by NGA. Such licenses exist, for example, for high-resolution commercial optical imagery through the NextView, EnhancedView, and ClearView contracts. Foreign data, particularly radar imagery, are available from Canada, Germany, Italy, and Japan.

If there are commercial data or products that could serve multiple NASA-funded communities and an all-government license does not already exist, NASA program managers can initiate such procurements. It is my understanding that as recently as August 2015, NASA issued a \$310,000 contract to DigitalGlobe for procurement of high-resolution imagery from specifically tasked RADARSAT-2 (Canada) and other systems during disasters and other sensitive areas, to augment NASA uses of NGA-supported archived imagery.

Given the complexity of possible data licenses, NASA has to take special care in archiving and distributing commercial data. In accordance with national and

international open data policies, NASA makes all non-commercial data freely and openly available through its data systems. When individual scientists (e.g., principal investigators) purchase commercial data products, they generally keep ownership and are governed by their purchase licenses regarding any sub-distribution. When NASA procures commercial data products, it attempts to negotiate the most open license possible, but must respect any contractual restrictions when data products are on NASA data systems.

From a NASA Earth science point of view, the mission is to advance Earth system science and to develop, test, and demonstrate applications for public benefit. The sources of data, value-added products, or other information is not of concern provided the data (and associate metadata) are stable, well-characterized, and of sufficient quality. This is largely similar to the view in the NGA Commercial GEOINT Strategy. If there are non-agency customers who might be able to bear some portion of fixed costs, then the agency can do a make or buy analysis. If the agency is the only customer, as is the case for almost all Decadal Survey Earth science data, then a government build is the only realistic choice. Looking beyond initial data acquisition, commercial providers could be part of data archiving, processing, and analysis functions where government-unique data resides on the same hosting infrastructure as commercial users.

In the case of Landsat, the technical risks in providing the data are well bounded and there are multiple non-NASA users. Given the right incentives, commercial entities could fund the development, test, and operation of systems to provide Landsat continuity data. However, the intent of Congress has been that NASA would develop a next-Landsat satellite, rather than examine the designs of innovative systems and partnerships as recommended by the Decadal Survey. The NASA Appropriations Conference Report for FY 2015 states: "The Committee [Conference] does not concur with various administration efforts to develop alternative "out of the box" approaches to this data collection —whether they are dependent on commercial or international partners."² In this case, as in 1992, innovation was less of a priority than reduced perceived risk of a gap in Landsat data continuity.

The current policy of free access to Landsat data is working well and I would not try to "commercialize" it. But I do think that innovation is possible in how the data are acquired. While proceeding with Congressional direction to purchase another Landsat satellite, there could be a parallel pilot program to buy Landsat continuity data specifically from a non-Landsat source to demonstrate feasibility. After having some experience, NASA could make a more informed decision about acquiring another spacecraft. Similarly, GPS radio occultation (RO) data were seen as potentially available from private U.S. sources almost two decades ago but partnerships with a foreign government were preferred. A pilot program to purchase GPS RO data to improve atmospheric modeling could enable a more

² U.S. Congress, Omnibus Appropriation Bill and Conference Report for FY2015, H.R. 83, December 11, 2014, Washington, D.C.

informed decision about how and whether to expand the use of such data beyond the current successful partnership with Taiwan and COSMIC satellites.

Public-Private Partnerships

The phrase “public-private partnership” is an increasingly popular one for space activities. Unfortunately, what the term means in any particular case is often hard to discern. It can represent agency hopes that private capital will pay for developments for which it does not have the budget. On the industry side, there may be expectations that the government will reduce potential market and financial risks to enable an otherwise unprofitable venture to proceed. This is not to say that mutually beneficial public-private partnerships cannot exist but rather a clear understanding is needed of the allocation of costs, risks, and benefits on both sides.

In policy, it is instructive to compare the 1991 definition of commercial space activity with the current national space policy:

<h2>Compare and Contrast Definitions</h2>	
<p>U.S. Commercial Space Policy Guidelines February 11, 1991</p> <p>Commercial space sector activities are characterized by the provision of products and services such that:</p> <ul style="list-style-type: none"> • private capital is at risk; • there are existing, or potential, nongovernmental customers for the activity; • the commercial market ultimately determines the viability of the activity; and • primary responsibility and management initiative for the activity resides with the private sector. 	<p>U.S. National Space Policy June 28, 2010</p> <p><u>Commercial Space Guidelines</u></p> <p>The term “commercial,” for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that</p> <ul style="list-style-type: none"> • bear a reasonable portion of the investment risk and responsibility for the activity, • operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and • have the legal capacity to offer these goods or services to existing or potential nongovernmental customers.

The 1991 definition is stricter in its emphasis on market forces while the 2010 definition is looser to allow for government supports and mixing of public and private goods. In the case of commercial remote sensing, there are a variety of potential benefits, costs and risks to NASA or any government agency. The agency

can save development costs and reduce its portion of sustaining fixed costs if a private sector partners has multiple non-agency customers, preferably outside the U.S. government. The private sector need not follow the constraints of federal acquisition regulations and thus may able to operate more efficiently and rapidly. For companies, reliable agency purchases can lower financial and market risks although this depends on the type of contract mechanism.³

For both agencies and companies, it is common to find that each wants only to pay the marginal cost of having a capability rather than the average cost. Each will want the other to bear the fixed costs and risks. If the dominant market demand is for a public good, then the burden rightly falls on the government. If the dominant market demand is from the private customers, the burden should be borne by the private sector. In many cases of civil remote sensing, like Landsat, the roughly even balance of public and private demand makes a clear partnership more difficult, not easier.

A notional agency perspective on public-private partnership (PPP) is shown in the strengths-weaknesses-opportunities-threat (SWOT) chart below.

Agency SWOT Perspectives on PPP

Strengths	Weaknesses
<p>Potential for cost and schedule efficiencies (costs factors of 3-7x)</p> <p>Attraction of non-government stakeholders to support the partnership</p> <p>Opportunities</p> <p>Allows agency to reallocate attention and resources to higher priority objectives</p> <p>Attraction of private investment that aligns with government missions</p> <p>Allows for more innovative experiments</p>	<p>Less opportunity to build in-house expertise</p> <p>Unrealistic or optimistic expectations that misread cost, schedule, and demand and create implicit risks</p> <p>Fewer accountability mechanisms for performance and insight</p> <p>Threats</p> <p>Policy and budget instability</p> <p>Private investment fails to occur, private providers fail to perform, and public missions placed at risk</p> <p>Becoming captive to a monopoly supplier, lack of government IPR</p>

³ Either cost-plus or fixed price contracts can work depending on the conditions and allowable margins. Neither is intrinsically better than the other.

The purchase of data as opposed to ownership of a satellite system means a subtle shift in the role of the agency toward being a consumer of what industry chooses to provide rather than a customer who specifies what is to be provided. For agencies, including NASA, there are strengths, weaknesses, opportunities, and threats associated with the use of commercial data and public-private partnerships to meet their mission needs. Among the strengths and opportunities are the potential for cost savings, more rapid innovation, and the alignment of private investment with public good needs. Among the weaknesses and threats are a loss of in-house expertise, dependency on private resources for the performance of public missions, and fewer mechanisms for agency control of cost, schedule, and performance.

Choices for Government Uses of Commercial Data

If the government needs certain kinds of data, an independent and objective “make versus buy” analysis can help decide whether it should own and operate its own system or buy the data from an outside supplier. In some cases, the rights to access and distribute privately owned data for scientific research might simply need to be purchased. The government has no right to free access to other forms of private intellectual property even for purposes of scientific research.

On the other hand, as the experience with Landsat shows, efforts to sell many kinds of space-derived data may make no economic sense. Free distribution of data can result in greater public and private benefits if users are not initially deterred by prices, even low ones. The promotion of commercial remote sensing is sometimes seen as being in competition with the open exchange of scientific data, as defined by the data sharing principles of the Group on Earth Observations. This need not be the case and a “one size fits all” policy should be avoided that either infringes on private property rights or encourages governments to act like for-profit firms.

For policy-makers and industry, a primary task is getting an objective market analysis. Privatization is when industry provides goods and services previously provided by governments. Commercialization is a more difficult task in that industry has to serve private demand in addition to government demand. Meeting private market demand with competing private providers using private capital at risk is the essence of commercialization. It can be difficult to assess the size of addressable markets for new data products and judge the amount of capital required to come to market. Yet doing so is a necessity in deciding whether commercial data buys are viable and sustainable.

For agency leaders, they need to conduct their own analyses of alternatives in how to best meet their mission requirements. In deciding whether to “make” data with their own system or to “buy” data from others, NASA needs to decide how to allocate risks between what it provides and what it expects others to provide, to assess the regret costs if a private provider fails to perform as expected, and what fallback options exist. Most critically, NASA needs to gain and retain in-house expertise to

ensure due diligence and oversight of public funds, whether used for traditional acquisitions, public-private partnerships, or commercial purchases.

Concluding Thoughts

Today, NASA is facing both opportunities and challenges in taking advantage of an increasingly sophisticated, innovative commercial remote sensing industry to meet mission needs. Industry capabilities are greater than ever before, but so are the budget pressures and expectations placed on NASA Earth Science to meet the nation's needs for everything from cutting edge science to the sustainment of climate monitoring capabilities and practical social benefits from Earth science.

Agencies are in an extended process of sorting out which roles and responsibilities they are best at performing. Major elements of NASA's Earth science programs will likely remain government-led due to the lack of commercial demand for specialized scientific data. Commercial providers will not soon replace unique platforms, such as those in the A-Train. On the other hand, where NASA needs can be met by commercial data sources, cooperation with other agencies like NGA can increase the government's buying power. Similarly, NASA already acquires weather satellites on behalf of NOAA as it has the internal expertise to do so more efficiently.

In acquiring commercial data, NASA should ensure it gets sufficient rights so that data sets can be shared for scientific, non-commercial purposes. It should also ensure that it has sufficient insight into how the data were generated so that scientific peer review can independently assess conclusions based on those data.

There should be procurement "on-ramps" to enable experimentation and large-scale innovation in parallel with current government systems and international partnerships. In its own self-interest, NASA should be open to alternatives as industry develops. In the long term, it will be more risky to pursue only traditional acquisitions without a mixed portfolio that includes non-traditional and commercial procurements.

Finally, NASA should continue to be a strong domestic and international advocate of preventing interference to the radio spectrum upon which remote sensing relies. Spectrum protection is and will continue to be challenging due to commercial terrestrial communications demand for more spectrum.⁴

Thank you for your attention. I would be happy to answer any questions you might have.

⁴ This particularly includes the Earth Exploration Satellite Service (EESS) used for remote sensing, and the Radionavigation Satellite Service (RNSS) used by GPS.

Scott Pace

Dr. Scott Pace is the Director of the Space Policy Institute and a Professor of the Practice of International Affairs at George Washington University's Elliott School of International Affairs. He is also a member of the faculty of the Trachtenberg School of Public Policy and Public Administration. His research interests include civil, commercial, and national security space policy, and the management of technical innovation. From 2005-2008, he served as the Associate Administrator for Program Analysis and Evaluation at NASA.

Prior to NASA, Dr. Pace was the Assistant Director for Space and Aeronautics in the White House Office of Science and Technology Policy (OSTP). From 1993-2000, Dr. Pace worked for the RAND Corporation's Science and Technology Policy Institute (STPI). From 1990 to 1993, Dr. Pace served as the Deputy Director and Acting Director of the Office of Space Commerce, in the Office of the Deputy Secretary of the Department of Commerce. He received a Bachelor of Science degree in Physics from Harvey Mudd College in 1980; Masters degrees in Aeronautics & Astronautics and Technology & Policy from the Massachusetts Institute of Technology in 1982; and a Doctorate in Policy Analysis from the RAND Graduate School in 1989.

Dr. Pace received the NASA Outstanding Leadership Medal in 2008, the US Department of State's Group Superior Honor Award, *GPS Interagency Team*, in 2005, and the NASA Group Achievement Award, *Columbia Accident Rapid Reaction Team*, in 2004. He has been a member of the US Delegation to the World Radiocommunication Conferences in 1997, 2000, 2003, and 2007. He was also a member of the US Delegation to the Asia-Pacific Economic Cooperation Telecommunications Working Group, 1997-2000. More recently, he has served as a member of the U.S. Delegation to the UN Committee on the Peaceful Uses of Outer Space in 2009, and 2011-15. Dr. Pace has been a member of the NOAA Advisory Committee on Commercial Remote Sensing (ACCRES) since 2012. Dr. Pace is a former member of the Board of Trustees, Universities Space Research Association, a Member of the International Academy of Astronautics, an Associate Fellow of the American Institute of Aeronautics and Astronautics, and a member of the Board of Governors of the National Space Society.

Chairman BABIN. Yes, sir. Thank you, Dr. Pace. I appreciate it. I now recognize Dr. Scott for five minutes to present his testimony. Dr. Scott, thank you.

**TESTIMONY OF DR. WALTER SCOTT,
FOUNDER AND CHIEF TECHNICAL OFFICER,
DIGITALGLOBE**

Dr. SCOTT. Thank you, Mr. Chairman.

I'd like to acknowledge that 23 years ago, with its support for the 1992 Land Remote Sensing Policy Act, this Committee set in place the framework that enabled commercial space observation of the Earth to be born and to set the stage for what's turned out to be a very successful public-private partnership.

Over 23 years ago, when I started DigitalGlobe, the Cold War had ended, and the global transparency that had been provided by satellite reconnaissance had contributed to keeping the Cold War cold because it allowed nations to act on the basis of facts, not on the basis of fears. Along the way, the Landsat program introduced the world to satellite imagery in 1972, and this led me to wonder, couldn't those benefits be more widespread? Imagine if there were fewer instances of hunger, thirst, strife, sickness around the world. Wouldn't that lead to increased global stability and a greater quality of life for mankind?

So now roll the clock forward. The satellite—high-resolution satellite imagery industry was successfully commercialized and brought to market in 2000 supporting customers that include a wide range—energy, financial services, U.S. allies, U.S. government, online mapping. If you've looked at satellite imagery on your mobile devices, it's probably DigitalGlobe's. And in many ways, satellite imagery—the satellite imagery industry represents an ideal model for public-private partnerships.

In our case specifically, we've been a trusted partner of the U.S. government for more than a decade, most recently with NGA's Enhanced View SLA, which is a ten-year firm fixed-price contract where the government pays for the products and services that it receives but not for the infrastructure, the overhead, the workforce, or any of the associated costs of a traditional government acquisition. And today we provide NGA with over 90 percent of their foundational Earth imagery requirements. They get first priority tasking to our high-resolution unclassified imagery, and it can be shared broadly to support operational mission planning, disaster response, recovery, and situational awareness.

So what are some of the key lessons learned from that public-private partnership? The first one is to balance the needs of the U.S. government with a commercial partner. We make our money by collecting imagery and then licensing it multiple times to different customers for use in different ways. As such, if a customer is allowed to widely and freely disseminate the totality of our products, it undermines our ability to deliver commercial value, and so there are models in which we could make all of a certain type of imagery available for broad sharing as Landsat is today but at a higher cost to the government to offset the loss of the commercial opportunity, and the government would need to make that tradeoff.

The second key point is, it's critical to have a predictable regulatory regime that's designed to foster innovation. This is extremely important to us, and I'd like to thank the recent support by this Committee on the SPACE Act that was passed last night, specifically Chairman Bridenstine and Congressman Perlmutter—thank you very much—who championed the remote sensing language that I believe is a needed first step to regulatory reform. If you think about it, the current regulations in our industry were written at a time when very few players outside the government were capable of remote sensing, and the world is obviously very different now where there are billions of people who use the internet to access satellite imagery, and there are hundreds of remote sensing satellites being launched by dozens of nations.

The United States played a critical role as an international leader in the space industry, and to maintain and extend our leadership, we need a regulatory framework that encourages that leadership and staying well ahead of and not simply achieving parity with foreign competition.

So in closing, I want to thank you for the opportunity to describe our unique public-private partnership with NGA. It's been our honor to work with NGA, which is unwavering in its efforts to secure our Nation, and we share a commitment to that service and it's why so many of our employees have chosen to spend their careers at DigitalGlobe. There's no higher honor than serving those who serve our country, and that's how we live up to our purpose of seeing a better world.

Thank you.

[The prepared statement of Dr. Scott follows:]

1 **WRITTEN TESTIMONY for Walter Scott**
2 _____

3 **Written Testimony**

4 **Statement of Walter Scott**

5 **Founder, Executive Vice President and Chief Technical Officer of DigitalGlobe**

6 **Committee on House Science, Space and Technology**

7 **Subcommittees on Space and Environment**

8 **November 17, 2015**

9
10
11
12 Chairman Babin, Chairman Bridenstine, Ranking Member Bonamici, Ranking Member
13 Edwards, and distinguished members of the subcommittees, on behalf of DigitalGlobe, I would
14 like to thank you for the opportunity to testify on the viability and steps needed for successful
15 public-private partnerships in support of future earth observation systems and associated NASA
16 data requirements.

17
18 **Importance of Earth Observation Systems**

19
20 Imagine if there were fewer instances of hunger, thirst, strife, and sickness around the world.
21 Undoubtedly, this would lead to increased global stability and greater quality of life for mankind.
22 Earth observations systems are a fundamental component of the protection of human life and
23 property, economic growth, national and homeland security and scientific research. Today, we
24 have an opportunity to observe the earth in ways that can alert us to new risks, better inform
25 decisions, and create new opportunities for societal advances. Because our planet is constantly
26 changing, there is a great need for products and services that deliver accurate, current
27 information about the environment in which we live and operate.

28
29 The Landsat program introduced the world to satellite earth imagery in 1972, and high-resolution
30 satellite imagery was commercialized and brought to market in 2000. In fact, it was this
31 committee who was instrumental in enabling the commercialization of satellite imaging
32 technology with its support of the original 1992 Land Remote Sensing Policy Act. Since that
33 time, private sector activity within the remote sensing industry has experienced significant
34 growth and taken on an increasingly larger role in serving the U.S. government, its allies, and a
35 broad range of commercial industries, from the online mapping and technology sector, to energy,
36 to financial services. In many ways, the satellite imaging industry represents an ideal model for
37 public-private partnerships, given the increasing demands from the public sector and the private
38 sector's ability to accelerate innovation and build the necessary capabilities to meet these
39 demands and deliver value.

40
41 **About DigitalGlobe**

42
43 DigitalGlobe is a satellite imagery and geospatial information company driven by our purpose of
44 Seeing a better world™, which guides all that we do. We are a leading global provider of
45 commercial high-resolution earth observation and advanced geospatial solutions that help
46 decision makers better understand our changing planet in order to save lives, resources, and time.

47 DigitalGlobe is a publicly traded U.S. company, headquartered in Westminster, Colorado, with
48 nine offices around the world that collectively employ approximately 1,300 people.

49
50 DigitalGlobe owns and operates the world's most advanced commercial satellite imaging
51 constellation, with four satellites (WorldView-1, WorldView-2, GeoEye-1, and WorldView-3)
52 that collect more than 1 billion sq. km. of sub-meter-resolution imagery per year, six times the
53 land surface area of earth each year. We will launch our next satellite, WorldView-4, next
54 September, which will extend our leadership in the industry. We have invested significant
55 resources in building unique capabilities that enable us to be a trusted mission partner that
56 enables military planning and operations, informs policy-making, intelligence analysis,
57 navigation, and humanitarian/disaster relief.

58
59 To put our capabilities into context:

- 60
- 61 • DigitalGlobe maintains the industry's deepest archive of high resolution imagery, with
62 more than *6 billion sq. km.* of imagery -- 40x the world's landmass -- spanning *15 years*
63 of satellite collections.
 - 64 • We manage a total commercial data volume of approximately 100 petabytes, to which we
65 add 10 petabytes annually.
 - 66 • We are able to capture imagery of anywhere on earth multiple times per day.
 - 67 • Some of our satellites see parts of the spectrum beyond what the human eye can detect,
68 and this valuable information can tell us, for example, what material a building's roof is
69 made of, where are the solar panels, what type of mineral we are looking at, or the health
70 and type of vegetation we are looking at.
 - 71 • Our satellites can see objects as small as home plate on a baseball diamond.
 - 72 • Our archive houses an exponentially growing amount of metadata about the world, with
73 detailed particular information behind each image captured, which further allows our
74 users to understand the world around them.

75 76 **Our Experience with Public-Private Partnerships**

77
78 DigitalGlobe has been a trusted partner of the U.S. Government for more than a decade. In 2010
79 DigitalGlobe entered into its most recent long-term partnership with the National Geospatial-
80 Intelligence Agency (NGA). As you are aware, NGA is the nation's primary source of
81 unclassified geospatial intelligence, or GEOINT for the Department of Defense and U.S.
82 Intelligence Community. What you may not know is that DigitalGlobe provides NGA with over
83 90% of its foundational earth imagery requirements, supporting operational mission planning,
84 disaster response and recovery, and situational awareness. We do so through EnhancedView, our
85 10-year (one base year plus nine option years), firm fixed-price contract. EnhancedView is a
86 Service Level Agreement (SLA), meaning that the government only pays for the products and
87 services it receives -- not the infrastructure, overhead, and workforce costs that accompany
88 traditional government acquisition programs. In this case, NGA receives first-priority tasking
89 access to our high-resolution imagery satellites and unclassified imagery products that can be
90 shared broadly to support national security requirements.

91
92

93 **Rationale and Benefits of Public-Private Partnerships**

94
95 NASA has an unmatched legacy of innovation that is the envy of national space programs
96 around the world. But for any agency that grew up doing the impossible, there is a tendency to
97 approach every problem, no matter how mundane, with the same approach. This was great for
98 missions like putting a man on the Moon or sending a spacecraft to Pluto. It's not so great for
99 problems that no longer occupy the bleeding edge, and which can either be partially or
100 completely addressed by current or emerging commercial data sources.

101 Furthermore, the U.S. National Space Policy of 2010 was extremely prescriptive in its position
102 on the U.S. Government's acquisition and use of commercial space services. Specifically, U.S.
103 departments and agencies were directed to:

- 104 • Purchase and use commercial space capabilities and services to the maximum practical
105 extent when such capabilities and services are available in the marketplace and meet
106 United States Government requirements;
- 107 • Actively explore the use of inventive, nontraditional arrangements for acquiring
108 commercial space goods and services to meet United States Government requirements,
109 including measures such as public-private partnerships, hosting government capabilities
110 on commercial spacecraft, and purchasing scientific or operational data products from
111 commercial satellite operators in support of government missions; and
- 112 • Develop governmental space systems only when it is in the national interest and there is
113 no suitable, cost-effective U.S. commercial or, as appropriate, foreign commercial service
114 or system that is or will be available.

115 The numerous U.S. agencies that rely on space-based capabilities have been pursuing innovative
116 commercial partnerships in recent years as a result of this Policy. NASA itself is, of course, very
117 familiar with these types of arrangements, having implemented them to resupply the
118 International Space Station, and, eventually, send U.S. astronauts there. The U.S. Air Force has
119 pursued a number of opportunities to host U.S. Government payloads on commercial spacecraft,
120 and it plans to outsource the operation of its Wideband Global Satcom (WGS) communications
121 satellites to a commercial firm next year. If successful, this program could serve as a pathfinder
122 for commercial operation of other government constellations such as the Global Positioning
123 System, service officials have said. And, of course, NGA's EnhancedView program.

124 To that end, we believe these kinds of innovative public-private partnerships can and do provide
125 specific, considerable advantages to the U.S. government:

- 127 • **Cost Savings.** An SLA allows the government to know exactly what it will be paying to
128 fulfill its needs, as it encompasses everything required to build, launch, and operate a
129 system under a firm fixed-price contract. DigitalGlobe has invested billions of dollars not
130 only building its fleet, but also the secure operations, a global network of a dozen ground
131 stations, and a communications and processing infrastructure that supports operations.

132 Additionally, we are able to provide a greater value to the government because costs are
 133 spread across both USG and commercial customers. In all actuality, it's not only far
 134 cheaper than acquiring a similar USG-owned capability, but it's also a fraction of market
 135 price.

- 136 • **Mutual interest in delivering performance and value.** As a commercial company,
 137 DigitalGlobe succeeds only when we provide value to our customers. If we do not
 138 provide the value demanded by our customers, including the NGA, then we will not
 139 succeed as a commercial company. It's the difference between building a house for
 140 someone else, and building the house that you live in yourself. This is why we have
 141 delivered such a high level of performance to NGA; despite the very high—and
 142 increasing—level of performance they demand, we have exceeded this performance for
 143 the past consecutive 40 months without fail.
- 144 • **Innovation.** As a commercial company in a highly competitive industry, we must
 145 constantly innovate to meet the needs of our customers, which operate on much faster
 146 product cycles than the government. This has a reciprocal benefit for the U.S.
 147 government, our largest customer, as it leverages investments we make to serve our
 148 commercial customer base, driving greater efficiencies in the products and services we
 149 deliver. We are pleased to see that NGA, our largest customer, is leaning forward in
 150 leveraging this trend of commercial innovation.
- 151 • **Sharable.** In today's coalition environment, sharable information is essential. The
 152 unclassified nature of our imagery means that it is actually possible to share with our
 153 allies and coalition partners. Our imagery provides credibility and transparency when
 154 dealing with geopolitical issues across the world. For example, in 2014, following the
 155 crash of Malaysia Airlines Flight 17, the Director of National Intelligence released
 156 DigitalGlobe imagery to show Russia's involvement in Ukraine. In releasing the images,
 157 the Pentagon stated that the photos "provide evidence that Russian forces have fired
 158 across the border at Ukrainian military forces, and that Russia-backed separatists have
 159 used heavy artillery, provided by Russia, in attacks on Ukrainian forces from inside
 160 Ukraine." However, sharable does not mean publicly releasable, as I'll speak in the
 161 next section.

162 **Keys to a Successful Public-Private Partnership**

163 While there are many significant advantages to public-private partnerships, there have also been
 164 some tough lessons learned in the past decade. In considering the viability of a public-private
 165 partnership to support NASA's Earth observation program, we would stress a few important
 166 considerations in order to ensure that any program is successful:

- 167 • **Balance the needs of the U.S. government with your commercial partner.** As a
 168 business, DigitalGlobe has a responsibility to deliver a return to its shareholders. Given
 169 the capital-intensive nature of our business, we must invest significant resources and
 170 capital to build the required network and satellites to be a mission-critical partner for an
 171 agency like NGA. Much like computer software companies, we make our money by
 172 building—or collecting—once, then selling (or, more accurately, licensing) that imagery
 173 multiple times to different customers. As such, if a customer is allowed to widely or
 174 freely disseminate our products, then their commercial value is diminished or outright
 175
 176
 177

178 destroyed. There is potentially a model in which we could make all of a certain type of
 179 imagery publicly available, as Landsat data is today, but at a much higher cost to the
 180 Government in order to offset the opportunity cost of not being able to sell it to other
 181 customers. The Government would need to make the tradeoff between completely open
 182 availability at much higher cost to the Government versus, for example, a lower cost for
 183 open availability for research but not for open dissemination.

- 185 • **Promote a predictable regulatory regime designed to enable innovation.** Our
 186 industry is regulated by statute to ensure compliance with U.S. law, foreign policy and
 187 national security objectives. It must be recognized, however, that most of the current
 188 regulations were written in a time where there were very few players outside the
 189 government capable of remote sensing. Since that time, the world has changed
 190 drastically and technology is moving at a pace like never before. This begs for regulatory
 191 reform that will encourage this innovation and allow U.S. companies to stay ahead of
 192 their international competitors, instead of burdening them with outdated, unnecessary
 193 administration. Regulatory overreach or regulations that are improperly applied are
 194 having great impacts to industry—it stifles progress and creates an uneven playing field
 195 for U.S. commercial companies competing with foreign subsidized competitors. A
 196 consistent approach to both regulation and licensing can send an important signal to
 197 commercial entities that you welcome their involvement and are committed to being a
 198 strong partner over the life of a contract. The U.S. has played a critical role as an
 199 international leader in the space industry, and to maintain and extend our leadership, we
 200 need a regulatory framework that ensures that leadership, staying well ahead of—not
 201 simply achieve parity with—foreign competition. The U.S. government must tailor policy
 202 and regulations to reflect the fact that remote sensing is no longer a U.S. only, exclusively
 203 government based effort, but instead a global technology that contributes to national
 204 security, commerce, disaster relief and so much more. After all, when the original
 205 legislation was passed in 1992, the Internet had only been available to the public for a
 206 little over a year; today, well billions of people use the Internet on their desktops and
 207 smart phones to access satellite imagery. It's a vastly different world today; shouldn't the
 208 regulatory framework be updated to reflect that?
 209
- 210 • **Promote transparency and stability in budgetary process.** The budget climate in
 211 Washington presents risks for any industry that works with the federal government. The
 212 near-constant commentary about potential cuts to defense spending has led to annual
 213 speculation—no matter how unfounded—about whether the NGA can renew
 214 DigitalGlobe's SLA, which accounts for a significant portion of our revenue base. The
 215 perceived uncertainty often impacts our ability to make long-term planning decisions and
 216 investments that would ultimately benefit our U.S. Government customer.
 217

218 **Unleash the Power of Public data sets**

219
 220 It's not enough to simply collect data if it can't be accessed by its end users. Public-private
 221 partnerships also provide a means for Government to get data into the hands of its end users and
 222 to do so efficiently and cost effectively. For example, DigitalGlobe operates the Global EGD
 223 ("Enhanced GEOINT Delivery") system on behalf of NGA for making high resolution,

224 orthorectified satellite imagery available to an estimated 100,000 government end users as
225 quickly as 12 minutes after it has been acquired. We support our commercial customers utilizing
226 the same platform for the data they have rights to access.

227

228 Similarly, we've leveraged the power of public cloud infrastructure, such as that offered by
229 Amazon, to enable Government and commercial users to perform big data analytics via our
230 Geospatial Big Data (GBD) platform against our enormous archive of imagery. By leveraging
231 cloud storage, cloud computing, data enrichment and analytic tools, and user-friendly application
232 programming interfaces, customers no longer need to have imagery or GIS expertise, or own and
233 operate heavy IT infrastructure, to extract useful information from huge imagery files. By
234 enabling users to bring their own algorithms and expertise to our data to do heavy data analytics
235 in the cloud, we've created an entirely new ecosystem of applications and use cases for our
236 imagery.

237

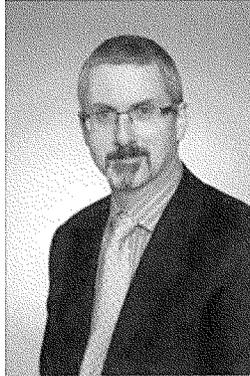
238 The result has been incredible interest from non-traditional earth imagery users. In the past year,
239 we've partnered with new companies that are using our imagery and platform to manage and
240 monitor commercial forests, track global-scale economic indicators for financial institutions, and
241 demonstrate the technology for a commercial drone air traffic management system. We believe
242 that there are opportunities to extend this model to Government funded datasets such as Landsat
243 and other earth observing systems, leveraging the scale with which commercial providers such as
244 DigitalGlobe are already operating at versus replicating this from scratch.

245

246 **Closing**

247

248 Thank you again for the opportunity to provide an overview of DigitalGlobe and our unique
249 public-private partnership with the NGA. It has been our honor to work with a partner like the
250 NGA, which is unwavering in its efforts to secure our nation. We share a commitment to service
251 and it's why so many of our employees have chosen to spend our careers at DigitalGlobe. There
252 is no higher honor than serving those who serve our country, and this is how we live up to our
253 Purpose of Seeing a better world™.



Dr. Walter S. Scott
Executive Vice President and Chief Technical Officer
DigitalGlobe

Dr. Walter S. Scott is our founder and currently serves as our Executive Vice President and Chief Technical Officer. Dr. Scott founded DigitalGlobe in 1992 as WorldView Imaging Corporation, which was the first company to receive a high resolution commercial remote sensing license from the U.S. Government (in 1993), under the 1992 Land Remote Sensing Policy Act. From 1986 through 1992, Dr. Scott held a number of technical, program and department management positions at the Lawrence Livermore National Laboratory, including serving as the Assistant Associate Director of the Physics Department. Prior to this, Dr. Scott served as President of Scott Consulting, a Unix systems and applications consulting firm. Since April 2013, Dr. Scott has served on the Board of Directors of The Open Geospatial Consortium (OGC), an international industry consensus standards organization. Dr. Scott holds a Bachelor of Arts in Applied Mathematics, magna cum laude, from Harvard College and a Doctorate and Master of Science in Computer Science from the University of California, Berkeley.

Chairman BABIN. Thank you, Dr. Scott.
I now recognize Mr. Schingler for five minutes to present his testimony.

**TESTIMONY OF MR. ROBBIE SCHINGLER,
CO-FOUNDER AND PRESIDENT, PLANETLABS**

Mr. SCHINGLER. Thank you, Chairman, and thank you very much to the Committee for inviting us here today and having this important conversation.

I would like to offer you my thoughts on how a changing landscape—and how the landscape is changing in commercial space activities. This suggests that NASA and other government agencies should rethink the nature of their relationship with the private sector.

The concept of public-private partnerships needs to expand to be inclusive of the full portfolio of activities where government and private sector efforts overlap and intermingle. A core objective of his suite of activities should be to encourage U.S. entrepreneurial ingenuity at this certainly is going to be a strong source of U.S. leadership in space in the 21st century.

I will speak specifically to opportunities in the realm of Earth observation to illustrate this larger concept, but this same framework is applicable to other challenges and opportunities that we face in space today.

Over the past several decades, in parallel to the pioneering work being done at NASA, a new world of sensor technology was emerging driven by the massive improvement in technologies from the commercial sector including consumer electronics, industries, biotechnology industries and the internet. What this means is the capacity is to have highly capable, sensitive, long-lived, low-cost components fielded in technology platforms in any location. We see this in our pockets. We see this in drones. We see this in our homes, in our cars. It's a global sensor revolution that's giving us near real-time data about the world around us.

So my cofounders and I, inspired to think big at NASA, wanted to bring the sensor revolution to space. So we formed PlanetLabs. Our first goal was to leverage the utility of having a distributed sensor network in space, and that is to image the world Earth every day, and we call that mission one, and the purpose of doing that is to make global change visible, accessible, and actionable.

To accomplish our goal of whole Earth everyday imaging, we're placing more than 100 satellites into a sun-synchronous orbit. Today we've launched a total of 101 test satellites over the last 2-1/2 years, and we are currently operating nearly four dozen spacecraft in two different orbits. Today we operate the world's largest Earth observation constellation, and given our pace of development and learning and our planned launch manifests over the next 12 months, we anticipate having the global daily monitoring capability from space operating this time next year.

PlanetLabs is one of several companies leading a new revolution in Earth imaging. Companies with a similar perspective on innovating quickly with new technology, pursuing a meaningful mission, and disrupting markets and industry sectors, companies that are privately funded looking for commercial market return first be-

fore approaching the government. These companies are bringing higher-resolution imaging, higher revisit Earth imaging, video from space, commercial weather data, and other capabilities to reality. Much of these technologies' industrial capability that is being developed lend itself to other missions in space, especially in areas where disaggregation and distributed sensory networks can be best utilized.

I am compelled to note that at Planet Labs, we consider ourselves to be in partnership with the civil government Earth observation community every day. For example, we use Landsat 8 data for many critical purposes. We use MODIS data, cloud data from NOAA systems. NASA and NOAA provide a critical foundation for our activities, and without their publically available data, we would be significantly challenged to accomplish our goals. Moreover, the longitudinal history and reliability of these systems are key for industry to prosper and for scientists to discover greater understanding of our planet.

Since the beginning of the space era in the middle of the previous century, space activities have had two extremely strong pillars: the national security space domain and the civil space domain led by NASA. The private sector has evolved to a point where it's certainly a third pillar into itself. Therefore, it is time to rethink a new structure for government contractor relationship with industry. A new industry-government relationship considers several factors holistically. These factors include government programs that foster innovation by creating white space for new concepts, creativity, and exploration that could led to new capabilities, products and services by the outcome, not the process, government programs that utilize kinds of agile aerospace methods practiced at planet and elsewhere to more rapidly advance their internal technology projects and train their professionals for multiple methods of program management, government agencies who can act as consumers in the market, able to recognize that they are one of many customers in a marketplace of new data and services, data buys for research and development and validation, and become a solid second commercial customer of a commercial product, and finally, a regulatory environment that is responsive and supportive to the innovations that come from the private sector, a good regulatory environment that has insight, oversight and foresight to foster commercial innovation.

Thank you very much. I have much more detail in the long-form testimony, and I look forward to answering your questions today.

[The prepared statement of Mr. Schingler follows.]

Perspectives on Public-Private Partnerships In U.S. Earth Observing Programs

Statement of Mr. Robert H. Schingler, Jr.
Co-Founder and President, Planet Labs, Inc.

Before a Joint Hearing of the Subcommittees for Space and Environment
of the
House Science Committee

November 17, 2015

Chairman Babin, Chairman Bridenstine, Ranking Member Edwards, Ranking Member Bonamici, Members of the Committees:

Thank you for inviting me here today to discuss with the Joint Subcommittee the issues of the the viability of public-private partnerships to support NASA's Earth observation program. My name is Robbie Schingler, and I am co-Founder and President of Planet Labs, Inc. a global commercial remote sensing company headquartered in California that aims to change the way we all see our world, and in particular how we can all see our world change.

I would like to offer you my thoughts about how a changing landscape in commercial space activities has built an environment in which NASA and other government agencies should rethink the nature of their relationship with private sector. The concept of "Public Private Partnerships" needs to expand to be inclusive of the full portfolio of activities where government and private sector activities overlap and intermingle. The primary objective of this portfolio of activities should be to ensure continued U.S. leadership in space activities, and should be inclusive of government programs and government regulatory efforts. I will speak specifically to opportunities in the realm of Earth observations to illustrate this larger concept.

NASA -- The First Revolution in Earth Imaging

In 1972, NASA changed the way we see our world, when the Astronauts of the Apollo 17 mission took a picture of the Earth from their vantage point in space, a picture famously called the Blue Marble photo. From then-on, through the 1970's until today, with programs like the Nimbus satellites, the Earth Observing System satellites, the LandSat program, and so on, NASA has been the world leader in building and operating the space systems that observe our Earth and pioneering the science of understanding its complex processes, how they interrelate, and how they change. NASA has international partners in these endeavours, and many countries now engage in some way toward a global capacity in observing and measuring the Earth. But there can be no doubt that NASA has been and remains the leader of this global community. It was NASA that first taught us about the value in consistently observing the Earth; the value in investing in new sensor technologies to do so; and the value of turning Earth observation data into a globally accessible public good. I will expand on this point below. In sum, NASA and

NOAA both teach us every day how our daily lives can be impacted when we have information from space at our finger-tips.

NASA is Planet Labs' Foundation

On a more personal level, NASA is where I grew up. I spent about ten years at NASA, starting as a research physicist at NASA Ames Research Center and taking on fun and challenging assignments between Ames and NASA Headquarters, starting the Small Satellite Mission Design Center to realize the Office of the Chief Technologist and Space Technology Mission Directorate. I can tell you first hand that NASA's workforce is the reason for NASA's successes. People are dedicated to the missions, working to unlock the questions of the cosmos and bring that understanding to help us live more sustainably here at home. But more than individuals following their north star within NASA's missions, people are compassionate, innovative and entrepreneurial -- people who invent new technology, ask entirely new and inspiring questions about our cosmos and our planet, and people who know how to thrive in a uniquely competitive and collaborative environment to advance the state of the art. It was at NASA that I became an entrepreneur, building teams and technology, looking for funding opportunities and human resources, and the need for a dedicated mission to pull individuals into teams and create that magic of innovation.

There Has Been a Parallel, Separate Revolution in Consumer Industries

Over the past several decades, in parallel to the pioneering work that NASA was doing, a new world of sensor technology was emerging. There has been massive improvement in the technologies of the commercial consumer electronics industries, biomedical/biotech industries, and the internet. We see the ruggedization of components, at low-power and low-cost; the growth in data storage and compute infrastructure; ever improving methodologies in big data analytics and machine learning; and continually advancing, highly capable manufacturing capabilities. These capabilities are most uniquely available here in the United States, they are available commercially, and they are affordable. What this means is the capacity to have highly capable, sensitive, long-lived, low cost components fielded in technology platforms in any location. We see it in our pockets with our highly capable mobile phones, we see it in our cars, in our homes - we see it in the sky with drones - but what about space? As my co-founders and I thought about what we saw around us, we wondered: why have we yet to see the sensor revolution in space?

Planet Labs and the Sensor Revolution in Low Earth Orbit

My co-Founders and I, inspired to think big at NASA, and challenged by colleagues we knew in other industries to innovate faster, posed a hypothesis to ourselves. What if we could build our own satellites without any aerospace companies, ride the new sensor revolution to iterate on them quickly and build a very capable, state-of-the-art sensor platform for space, and then mass manufacture those satellites in large numbers? Stated differently, if we can build a distributed, global sensor network in space, what could we do? A disaggregated sensor system leads to a resilient architecture for many missions - from scientific investigations and exploration

missions, to national security concepts, as well as novel commercial architectures for telecommunications, M2M and remote sensing. The remote sensing mission stuck with us and as we investigated it more deeply, there was absolutely a very unique social and market opportunity that lends itself quite well to this disaggregated space system.

What we did was form Planet Labs. Planet is a mission-driven company, founded to use space to help life on Earth. Our first goal, which we call Mission One, is to view the whole Earth from space, every day, and to make what we see from space accessible to all. Imaging the whole Earth, every day starts with our satellite constellations. At the heart of what will be our global imaging capability are our small satellites, which we call Doves, based on the cubesat standard. Our Doves are what are known as a 3-U cubesat, with dimensions of 10 x 10 x 30 centimeters. Our satellites are built with the most advanced, ruggedized and high performing technologies we could find; specifically sensors, connectors and integrated circuits that are part of an existing consumer electronics market cycle of increasing capabilities at decreasing costs.

We build our satellites rapidly, get them launched to space and tested often, and cycle through this process several times in short order. We call this Agile Aerospace, and we think it has been a great success. To date, we have launched a total of 101 R&D satellites to space, and we are currently operating nearly four dozen in two different orbits, providing useful imagery to us and our customers. We design our Doves ourselves; we build and integrate them ourselves in our San Francisco office; we test them and qualify them for launch ourselves; and once they are in space we have our own Mission Control where we operate close to 3 dozen ground stations to communicate with our satellites. Our Doves use a supply chain of sensors, electronics, and power supplies that come from the consumer electronics industry and other mass markets, meaning they evolve rapidly, are produced in large numbers at high tolerances while maintaining affordability, and can be quickly replaced almost on-demand. We have gone through thirteen total design iterations on our satellites, optimizing our supply chain and our internal quality assurance processes along the way.

To accomplish our goal of whole-Earth, every day imaging, we will be placing more than 100 Doves in a single, sun synchronous orbit. As many of the Members of these Committees know, sun synchronous orbit is an orbit used by most environmental observing satellites because it provides global coverage; though a single satellite, like Landsat, may need roughly two weeks to cover the entire globe, everywhere, at least once. By operating in excess of 100 Doves in sun synchronous orbit we will be able to image the entire globe, everywhere, every single day. With our constellation we will be able to see a new image of the same place on Earth, in every place on Earth, every day, in the Red, Green, Blue, and Near-Infrared bands. Given our pace of development and learning, and our planned launch manifest, we anticipate having the global, daily monitoring capability from space operating by this time next year.

Our Dove constellation is complemented by the RapidEye satellite constellation, which Planet Labs acquired as part of our acquisition of the Canadian-based BlackBridge Corporation. The RapidEye satellite constellation is five satellites, also in sun synchronous orbit, collecting imagery similar to our Dove satellites in both resolution and spectral bands. Combined, our

Dove and RapidEye constellations give Planet Labs the greatest commercial capacity for viewing the Earth at any one time.

As noted, Planet Labs operates as a commercial remote sensing company. We are focused on the mission at the core of our company -- to make global change, visible, accessible and actionable -- but we also need to wrap a business model around the company to be sustainable. Our customers are working with us now, in advance of Mission One, to develop early tools for the most beneficial utilization of our unique, high-revisit rate imagery. For the past two years we have been building an international customer base in several market verticals, such as agriculture, consumer mapping, finance, GIS services, big-data analytics, and others. With the addition of BlackBridge, now a Planet company, we've grown from launching our first satellites to having customers in over 100 countries in only two years.

Planet Labs is one of several companies leading a second revolution in Earth imaging. Companies with a similar perspective on innovating quickly with new technology, pursuing a meaningful mission, and disrupting markets and industry sectors. Companies that are privately funded, looking for a commercial market return first before approaching the government. These companies aim to bring higher resolution imaging, higher revisit Earth imaging, video-from-space, commercial weather data, and other capabilities to bear as the space-based Earth imaging contribution to the global sensor revolution.

NASA is Already a Key Enabler of This Second Revolution

I will expand on my ideas for what a Public-Private-Partnership means in the context of NASA's Earth Observations. But first, I am compelled to note that at Planet Labs we consider ourselves to be in partnership with the civil government Earth observation community every day. This based on the unparalleled foundation of openly available data NASA and NOAA collect, which I mentioned previously. We use Landsat-8 data for a variety of purposes: to help us accurately geolocate our satellite imagery and develop rectification algorithms; and to help calibrate our sensors and accurately color balance our imagery so that it most accurately reflects the true surface of the Earth. We use both Moderate Resolution Imaging Spectroradiometer (MODIS - <http://modis.gsfc.nasa.gov/>) data and Landsat data to help vary our camera setting to account for surfaces with different brightnesses. We use archived data from the Shuttle Radar Topography Mission (SRTM) and the the National Elevation Dataset for ortho-rectification of our data. We use cloud data from the NOAA NOMADS system (<http://nomads.ncep.noaa.gov/>), which provides global cloud cover forecasts (at different layers) for up to 10 days, which we use in part to help plan our satellite imaging operations. In sum, NASA and NOAA provide a critical foundation for our activities, and without their publicly available data we would be significantly challenged to accomplish our goals.

Continued Success Means Reframing the Industry-Government Relationship

In broad strokes, the changing nature of the space industry -- smaller more affordable satellites, the potential for more affordable launch, commercial entrants creating new missions and building new markets -- means we are on the cusp of the need for new thinking about how

the government and the private sector should communicate and collaborate to maintain U.S. leadership in space activities for the decades to come. Since the beginning of the space era in the middle of the previous century, space activities in the U.S. had two pillars - the national security space domain, and the civil space domain led by NASA. Broadly speaking, industry's relationship to the government was primarily as a contractor. And though industry clearly brought capabilities to the table, and to this day remains home to some of the greatest talent in the world, the government's requirements process, procurement regulations, and program management methods were at the forefront of new technology development and innovation. The private sector has evolved to the point where it is clearly a third pillar unto itself. It is therefore time to reconsider that historical government-to-contractor relationship.

A new perspective on the industry-government relationship considers several factors wholistically. These factors include:

- government agencies who can act as consumers in the market, able to recognize that they are one of many customers in a marketplace of new data and services;
- government programs that foster innovation by creating a white space for new concepts, creativity, and exploration that could lead to new capabilities, products, and services without constraining industry on how it is created;
- government programs that utilize the kinds of Agile Aerospace methods practiced at Planet and elsewhere to more rapidly advance their internal technology projects and train their professionals in multiple methods of program management; and,
- a regulatory environment that is responsive to and supportive of the innovations that come from the private sector, with an eye toward recognizing that more innovation happening in the U.S. industrial base is better for our national security than less, particularly in our current, globally competitive environment

I will try to address how these general factors can be applied specifically to NASA's Earth Observing programs and needs.

NASA is Poised to Start this New Kind of Relationship

The ISS Provides an Example Relevant to Earth Observations

In the area of creating a "white space" for innovation, as I noted, Planet Labs has launched 101 satellites to space so far. This has been on the back of 9 successful launches, the majority of which have been to the International Space Station (ISS), where they have been deployed into orbit from Nanoracks deployers. We have gone to the ISS a total of 5 times, out of which 4 were U.S.-based cargo launches. These latter launches were commercial launches enabled by NASA's COTS program, that upon transitioning to an operational capability created very frequent cargo missions to the ISS. Nanoracks has been a long-time partner with NASA to bring scientific and technology experiments to the ISS to fully utilize this national laboratory. The ISS has a predictable need for supply, which in turn creates a predictable launch manifest and secondary payload market. The ISS program is also making some of its external platform space available for commercial Earth observing opportunities, and the market is seeing the firms that take advantage of this expand into broader offerings not related to the need for ISS access.

This is an excellent example of NASA using its unique place in the space ecosystem to enable innovative ideas to emerge that are not tied to NASA's requirements.

A question facing NASA and industry general, when examining the success of ISS in this regard is -- how can this be replicated? Where within the technology programs, the science programs, and the data analysis programs across all of NASA can doors be open to industry that cost NASA little-to-no funds, give industry unique opportunities to access space, and allow for the development of new capabilities that can't otherwise emerge? NASA should be free to explore ideas like this with industry even more than they already do.

More Great Ideas Are Already Taking Shape Relevant to Future Earth Observing Needs

NASA recently announced that its Launch Services Program (LSP) has awarded new contracts for what it is calling Venture Class Launch Services (VCLS). These are contracts to new launch providers that are specifically targeted at providing increased, affordable, and reliable access to low-Earth orbit for small satellites. As NASA's press release about these recent contract awards note, these VCLS launches "are able to tolerate a higher level of risk than larger missions and will demonstrate, and help mitigate risks associated with, the use of small launch vehicles providing dedicated access to space for future small spacecraft and missions." It is noteworthy that NASA's Earth Science Division is jointly funding the VCLS awards, as small satellite applications to Earth science have the potential to be significant. NASA deserves great credit for taking this step toward fostering and nurturing the burgeoning small launch community -- it is another example, like the Commercial Cargo Program, that demonstrates how NASA can structure a program that creates benefits for multiple parties.

Another example comes from NASA's Space Technology Mission Directorate, which recently released a Request for Information (RFI) titled, "Pathfinder Technology Demonstrator," in which they sought information about how industry may respond to its needs for a rapidly provided spacecraft bus to enable integration of new payloads, and potentially future services such as Indefinite-Delivery, Indefinite Quantity (IDIQ) contracts for spacecraft and satellites as a service. Similarly, NASA JPL released an RFI to collect a catalog of ready spacecraft buses in either the 3-U or 6-U cubesat form factor. We believe that the idea at the heart of this RFI is precisely the right direction for NASA in this new era of a commercial space renaissance. NASA can intelligently leverage as much industrial capability as possible from across the entire landscape without having to define new requirements or justify new development program starts. Satellite bus hardware is a solved problem. Spacecraft manufacture, quality assurance, launch and commissioning, and autonomous operations are happening every day - including at Planet Labs. If NASA were to engage with industry to more rapidly access these capabilities in a truly commercial fashion where they can be available as a service, and then leverage that service to support NASA's unique needs, they could have a transformative impact on NASA's Earth observations programs, creating in-space test and demonstration opportunities for new sensors much more rapidly and at significantly lower cost than has ever been available.

We believe a program to work with industry on satellites-as-a-service can be complemented with internal-to-NASA projects that seek to rapidly develop new technologies and demonstrate them in space without following NASA's standard "Phase A, Phase B"

approach to project management. If given the opportunity to have more flexibility, if empowered to put the full weight of their skills and experience to work behind their ideas without strict adherence to all former practices, there is no doubt that the NASA workforce would unleash countless innovations and demonstrations that would bring about new revolutions in Earth science, space science, and planetary exploration.

Together We Can Continue to Expand the Scope for Earth Observing Needs and Benefits

Early Access Data Buys to Explore Unique Benefits of Collaboration

We think it is within the collective interests of Planet and other commercial providers to work with NASA and NOAA in support of shared goals and to contribute to the unique scientific, public-good mission of both agencies. We think cooperation and partnership starts with access to, utilization of, and dialogue on the benefit to NASA and NOAA of commercial data, including our data. There was no expressed, market requirement for daily, global data at 3-5 meter resolution before we started Planet Labs, yet we have been able to find commercial opportunities for the application of that data. We recognize that NASA may not have an established, previously documented requirement for that data either, and yet we are confident that there will be benefit to both NASA and NOAA, as well as others, from the application of this data. As an example, we are exploring with partners at the Carnegie Institution for Science in California and Woods Hole Research Center in Massachusetts how daily imagery of global forests can contribute to both our understanding of forest health worldwide, and our understanding of how measuring changes in those forests can translate into understanding changes in atmospheric carbon content. We know there are experts on this and countless other areas of investigation at NASA or NOAA who can even further unlock the potential of our data to add value to their work.

The U.S. commercial remote sensing industry, and NASA and NOAA, would all benefit tremendously if questions and examples like this were explored in a 1-on-1, targeted, collaborative evaluation process specific to scientific objectives that includes some combination of a data buy, customer feedback sessions, trial applications, and sharing of lessons learned. Indeed, the government may best position itself to efficiently utilize new commercial data streams as they come online if they enter into early partnerships while those data sets are still in development. For example, with Planet Labs, a short-term data buy for evaluation could offer unique insights into what daily, whole-of-Earth imagery could mean for NOAA or NASA's applications when it becomes available. Following that an appropriate arrangement can be made for global access based on a deeper understanding of its value and benefit to the government's mission. NASA and NOAA should therefore be encouraged and funded to explore the use of new or emerging commercially available data in an R&D-like environment to assess its benefit to different needs.

Reimagining How NASA and NOAA Data is Visible for the World

For Planet Labs, building a global monitoring space capability is only part of accomplishing Mission One. The capacity to collect imagery must be complemented by a

method of making that imagery accessible. More to the point, access to the imagery we collect, and the information it tells us about the change we see on our planet, should be intuitive, easy to manage, and tailorable to the needs of different kinds of users. We are building a web-based platform using the latest in cloud computing and cloud storage, with a front-end experience that we believe accomplishes that task. We want anyone to be able to search for, find, and compare imagery in ways that are important to them. We want developers to create applications that use our data and show meaningful change over different time scales, from days to seasons to years. We want a platform that allows anyone to bring their own, unique data sources and combine them with geospatial data and create new information to tell stories, build new maps, or direct resources to those in need.

It is not just Planet's data that should be made accessible in both a user friendly and powerful way. NASA's data is publicly available, as noted, but not always easily accessible to the lay-person. Our interest in extensive utilization of Landsat data as described above is part of the reason we worked closely with USGS to make Landsat data available to all via Amazon Web Services (<http://aws.amazon.com/public-data-sets/landsat/>). Landsat 8 data is available via our APIs as well. As part of any collaboration with NASA and NOAA we believe industry would bring ideas to the table for NASA that could revolutionize how people see their data, access it, make it part of their workflows, and integrate it into their daily lives to an even greater extent.

Utilize Multiple, Broad Authorities

In order to work effectively with industry to gain access to new data sources, collaborate on the evaluation of that data, and introduce industry to communities across the government space, the government should utilize all means at its disposal. For example, NASA should utilize commercial data buys via simple, commercial fixed price contracts or funded Space Act Agreements (SAAs), or both, depending on the specifics of a partnership or the interest of the specific firm. These may have to be in place in parallel with unfunded SAAs or Cooperative Research and Development Agreements (CRADAs) for information sharing and collaboration with other agencies. In all cases, the government should recognize that commercial firms often develop technology useful to the broadest possible market they can reach, and not specifically in response to a government-only requirement; and that maintaining their intellectual property is key to maintaining their differentiation in the market.

There is some Regulatory Risk to Commercial Success

The foundation of any successful, long-term relationship between government and the commercial remote sensing industry rests on the capacity of industry to provide commercial data, products and services on a reliable, predictable basis. This in turn relies on a predictable, reliable, and transparent regulatory environment that provides clarity of rules, consistency in implementation, and confidence to industry, investors, and the public at-large.

Our most frequent interactions with regards to the many agencies that touch on regulatory aspects of commercial, space-based remote sensing, are with the Office of Commercial Remote Sensing Regulatory Affairs within NOAA. This office has the lead responsibility for licensing private remote sensing space systems and coordinates the interagency process for these new

remote sensing capabilities, in coordination with the National Security Community. As this committee knows, the office has been operating under the weight of a continuously increasing number of applicants seeking licenses, pushing the boundaries of innovation in remote sensing. These applicants come from U.S. industry, from some international firms, and from an ever-growing university community that wants to use small satellite technology as a way to give students real hardware development experience. This increase in the number and diversity of prospective licensees has come without any significant increase in NOAA's capacity to respond. This office at NOAA is under-staffed, and under-resourced. If this trend continues NOAA's capacity to conduct even its most basic administrative functions may become unsustainable, and this surely is an unnecessary risk to the success of the U.S. commercial remote sensing industry. We encourage both the Administration and the Congress to increase funds to this NOAA office so that they can scale up with Industry, and provide a timely and responsive regulatory framework for industry. A robust regulatory team in the government has insight, oversight and foresight; it cannot be overly burdened with administrative tasks and not have the experts on the team to turn this industry opportunity into strengthening the third pillar of a robust US aerospace ecosystem.

Even with limited resources and over burdened staff, in general we are happy to report that our working relationship with NOAA, and the broader interagency community that works with NOAA, has been mostly positive. For example, in working with NOAA following our acquisition of BlackBridge, we were able to submit a license request to assume operations of the RapidEye satellite constellation and receive approval to do so in two months. We appreciated NOAA's willingness to coordinate an interagency review and provide us an answer in a timely, responsive fashion and to come up with a rational step-wise approach to balance national security concerns and globally efficient commercial operations. That said, we are concerned that, given the trends noted above, such timely responses may not be possible in the future.

In Conclusion - The Future is Bright

I hope that my remarks above provide to you the framework for a new relationship between government and industry, and a new perspective on what should be considered when we use the term "Public-Private-Partnership." NASA has excellent foundations under its feet for this already, with examples I provided above relevant to a new future supportive of innovation in general, but with specific value to the field of Earth Observation as well. As a former NASA employee it is my great pleasure to applaud these efforts. I have offered additional thoughts, and I hope both NASA and the Committee find them useful, around the ideas of data buys, and empowering NASA to experiment internally with Agile practices to empower their supremely talented workforce. And lastly, this framework goes beyond civil Earth Observation partnerships and can be applicable to arrangements for other U.S. government missions and needs. We are at the beginning of a space renaissance and in working between the strengthening commercial space industry and the government we will be on sustainable trajectory to maintain and grow our global leadership in aerospace.

Thank you for the opportunity to appear before you today, to share with you information about Planet Labs, and my opinions on the great potential for a substantial, substantive, and

mutually beneficial relationship between industry and the government in general, and between the growing commercial remote sensing sector and NASA, NOAA, and the civil agencies of the Federal government in particular. I look forward to answering your questions.

**Short Biography, Robert H. Shingler, Jr.
Co-Founder & President, Planet Labs**

Robbie Schingler is one of the founders of Planet Labs and today drives strategic projects including managing launch, government affairs and impact initiatives. Prior to Planet Labs, Robbie spent 9 years at NASA, where he helped build the Small Spacecraft Office at NASA Ames and was Capture Manager for the Transiting Exoplanet Survey Satellite (TESS). Robbie later served as NASA's Open Government Representative to the White House; and served as Chief of Staff for the Office of the Chief Technologist at NASA. He received a MBA from Georgetown University, a MS in Space Studies from the International Space University, and a BS in Engineering Physics from Santa Clara University. Robbie was a 2005 Presidential Management Fellow.

Chairman BABIN. Thank you, Mr. Schingler.
I now recognize Dr. Goward for five minutes to present his testimony.

TESTIMONY OF DR. SAMUEL GOWARD,

EMERITUS PROFESSOR OF GEOGRAPHY,

UNIVERSITY OF MARYLAND AT COLLEGE PARK

Dr. GOWARD. Thank you, Mr. Chairman.

I guess that I'm here representing the past and what we have or have not learned from it. So I think it's important to revisit Landsat, who I variously referred to as the albatross, as in the *Lost Mariner*, or the Rodney Dangerfield of land remote sensing, because it has suffered many, many tragedies over the years. The first started when the mission was first described and developed by an NRC panel in 1967 out at Woods Hole where the discussion of Earth observations led to the decision that land remote sensing would be most likely to commercialize. Unfortunately, that developed from a tradition of aerial photography, which preceded by a century this discussion of Landsat, and actually missed the point of the innovators and visionaries who first conceived of the Landsat mission, which was to be a global monitoring system, not a picture acquisition system, and in fact, that's been missed many times but actually the first Landsat mission was designed to have two satellites to demonstrate how you would develop an operational constellation to monitor Planet Earth as my colleague was just describing. Now, that was back in the 1970s when these designs were being developed, but it's never been captured as a part of the Landsat mission, and in fact, we've degraded since then, at least from my point of view.

It's important to recognize that because of the sense that Landsat was most likely to be commercialized as a substitute for aerial photography, it has suffered at least two examples of commercialization which have failed, the first of which was in the 1980s when the executive and Congress moved Landsat to NOAA and then commercialized the system with EOSAT. That was an experience that all of us involved in the science community still live in fear of today, and in fact, it's one of the reasons when you find scientists hesitating when we talk about private-public partnerships that the experience with EOSAT is clear still in everybody's minds.

Now, there are many lessons learned that I'm not going to go over today about what happened in that case, and we should never forget those lessons learned as we look to the future because, honestly, on the other side, I had been involved in the science data by convening a science panel to select the vendors that were chosen to provide products to NASA for Earth observations in the late 1990s, and we actually had a remarkable series of successes including the space imaging IKONOS data and we would have used DigitalGlobe and did very late in the process but there were launch issues that occurred prior to that.

So the second time that Landsat suffered a data buy issue is in the acquisition of Landsat 8, and under that process, the first process that was pursued was a data buy in which both Resource 21 and DigitalGlobe were involved. DigitalGlobe decided, probably for clear reasons, that they were getting out of that game before the bidding was selected, and Resource 21 was not selected because there was simply not cost savings involved to the government with the bid that they provided. But that's the second commercial effort for the Landsat mission, and I can tell you both of those efforts have put us behind in a science development of the value of this mission to observe the Earth as a result of those activities. So when you talk to the science community, you're going to get a very funny reaction about private-public partnerships, which is not necessarily a bad thing but you have to understand this history colors the view of the science community in the use of this approach to data acquisition.

However, it's important to also recognize that when Landsat came back to the government in the 1990s, that data buy became no longer an issue but the value of the data for science activity became very clear, and again, I won't go through the detail. I'm out of my time, so I'll stop here. Thank you.

[The prepared statement of Dr. Goward follows:]

Statement

Dr. Samuel N. Goward
Professor Emeritus

Space and Environment Subcommittees
Committee on Science, Space, and Technology

Public-private partnerships to support the NASA's Earth observation program

Chairman Babin (Space), Chairman Bridenstine (Environment) and members of the Committee. Thank you for this opportunity to present my views on NASA (and USGS) Earth observation programs, specifically the long-standing **Landsat mission**. These views are my own, which have evolved over more than forty years, from the beginning of my doctoral studies at Indiana State University.

The Landsat observatory was the first land imaging system flown by NASA in the early days of the Space Age¹. The system was originally designed to produce photography but did not use onboard film-based cameras but rather electronic video cameras and a novel multispectral scanner system. Earth scientists who had used aerial photography for nearly a century prior to the first Landsat launch, considered the Landsat images primitive and a step backward from their well-developed photographic technologies. The Landsat mission visionaries contrarily, viewed the Landsat concept as major new innovation, using space technologies to monitor global land dynamics the same way the weather satellites monitor atmospheric dynamics. The former, aerial photography vision for Landsat has generally dominated widely held impressions of the mission goals and therefore the potential for commercialization. In fact, in 1967 when decision makers met at Woods Hole, MA to discuss Earth observation applications, the land observations satellite was voted most likely to develop commercial potential based on the aerial photography perspective (National Research Council 1969). This conflict between global monitoring and local imaging has colored the dialogue about Landsat's role in the US culture ever since. As a result the Landsat mission has experienced more attempts to commercialize or privatize than any other NASA Earth observation mission

The Landsat mission, now approaching nearly 50 years in durations, experienced at least five different mission eras:

¹ DOD/CIA few earlier space missions under the CORONA but those images were only released recently for public use.

1. Multispectral remote sensing (1960-1970): Supported initially by DOD, particularly the Office of Naval Research, electronic scanning devices originally developed for intelligence gathering were made available to civilian researchers, particularly at the University of Michigan and Purdue University.
2. The Earth Resources Technology Satellite (1970-1973): USGS's William Pecora and Stewart Udall convince the nation and NASA to develop an Earth satellite to monitor land dynamics. Placed in orbit July 1972 ERTS-1 ((cum Landsat-1) it was initially employed to evaluate earth resources such as forests, grasslands, water and geology.
3. Agricultural Application (1973-1982): Russian wheat crop failure undetected by US agencies. The US grain reserves were sold for little profit. Congress and Executive instruct NASA, USDA and NOAA to employ Landsat technology to monitor global agricultural production. Large Area Crop Inventory Experiment (LACIE) followed by AgRISTARS (Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing) dominate Landsat activities for a decade (McDonald and Hall 1980). Remote sensing science developments during this era sets the ground work for later evolution of Earth systems science (Goward 1989).
4. **Commercialization** (1982 - 1992): NASA instructed to stop supporting other Federal Agency applications. Decision made to commercialize the Landsat mission. Landsat transferred to NOAA. EOSAT, a partnership of Hughes Aircraft and RCA, selected to operate Landsat. Cost of purchasing Landsat images balloons by a factor of 10. Legal restrictions prevent data sharing. Earth science use effectively stops, turning instead to NOAA AVHRR images.
5. Government Operations and Earth Systems Science (1992-current): The 1992 Land Remote Sensing Act returns Landsat, beginning with Landsat 7, to government management (DOD and NASA, then NASA and NOAA, then NASA and USGS). Landsats 4 and 5 taken over by USGS in 2001. NASA is directed to seek a **private-public partnership** for Landsat 8. Bids from Digital Globe and Resource21 explored. Digital Globe drops out. Resource21 not selected. Following various diversions NASA finally builds a free-flyer for Landsat 8, some 14 years after Landsat 7 launch. Current efforts to procure Landsat 9 have just begun with the initial profile being a replication of the Landsat 8 procurement.

The NASA Earth systems science activities provided substantial new opportunities for Landsat (Goward and Williams 1997). In particular, USGS removed COFUR costs in 2008 which caused the use to Landsat observations to skyrocket. Not only was there substantial pent-up demand but also contemporary computer systems, such as the NASA Ames NEX computing facility, can easily handle such data volumes. Not only is our understanding of land dynamics advancing in leaps and bounds but now the commercial potential of a high temporal repeat Landsat observatory is becoming clear.

This tortured Landsat pathway forward served to damage technical advancements and degraded overall mission performance, as the temporal repeat cycle of the system decreased. NASA anticipated replacing the optical-mechanical thematic mapper instrument with sensor array technologies in the 1980's about the same time the French flew a similar system. This ultimately did not occur until Landsat 8 was launched in 2013.

The original designers of the mission knew that a single satellite in sun-synchronous orbit would not be sufficient to accomplish the mission goals. The vision was for at least 4 satellites in orbit at any given time to provide four-day repeat nadir coverage. The initial two-satellite design for ERTS was intended to demonstrate the multiple satellite concept which was expected to further advance into an operational system. A similar logic is found in the simultaneous construction of Landsats 4 and 5, with the advanced thematic mapper sensor. When Landsat 7 is decommissioned in the near future, only Landsat 8 will remain, returning the community 16-day repeat observations. This will not be addressed until Landsat 9 is launched as currently planned in 2023. At which time Landsat 8 will have out lasted its anticipated design life. The 16-day repeat cycle has become the norm when this was never envisioned as suitable to Landsat's global monitoring mission (National Academies of Sciences 2015).

Today, with the maturing of new sensor and satellite technologies, the opportunity exists to fly at least four Landsat observatories at same total cost as a single satellite which uses the traditional using more technology of Landsat 8. The skeptics claim that these newer technologies have neither the capacity nor the reliability to meet Landsat mission standards. However this claim has never been tested.

A few years ago I served as principal investigator on a proposal developed by Global Science & Technology, Inc., in association with Surry Satellite US to fly a Landsat companion observatory for less than \$130 million, to supplement Landsat 8. This "TerEDyn" satellite did not include thermal infrared observations. More recently GST and Surry, with the support of NASA, have shown that fully

compatible, including TIR observations, could be flown for less than \$250 million, about one quarter the cost anticipated for a more traditional build for a future Landsat mission. Construction of this lower cost system could be completed in 3 years (e.g. 2018 if started now). Certainly GST and Surry are not the only businesses that are capable of taking this step (e.g. the EO-1 mission procured by NASA in the 1990s).

What is needed currently is a push to get NASA and the US private sector moving in the right direction. They need to step away from increasingly expensive single satellite builds toward lower cost, high temporal repeat Landsat class observatories which will better serve the rapidly advancing needs of Earth System scientists and the applied users supported by the private sector.

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Dr. Goward was born and raised in Lowell Massachusetts. Both of his parents were teachers which gave the family the opportunity to spend summers on Cape Cod, building their own summer house. He attended Boston University where he received both B.A. and MA degrees in Geography. His M.A. studies were interrupted by military service, where he served as a radar operator in a U.S. Army Nike-Hercules battery. In 1974, Dr. Goward was admitted to the Geography Doctoral Program, Indiana State University (Terre Haute, IN). This provided him the opportunity to learn the newly emerging field of remote sensing, with the Landsat mission having been launched two years earlier. Upon completion of his PhD he moved to Columbia University and the NASA Goddard Institute for Space Studies on the Columbia campus, primarily working on the NASA Large Area Crop Inventory Experiment(LACIE) and the AgRISTARS research programs, the first major global applications of the Landsat program. In 1982, he moved to the University of Maryland to work with colleagues at the NASA Goddard Space Flight Center, where he helped build the UMD Geography Department into a leader in its field while also developing a major research program. He retired from UMD this last July at age 70.

Throughout his career Dr. Goward has been involved in the Landsat mission, developing its capacity to monitor Earth resources and environment. He also served as the co-Chair of the USGS National Landsat Archive advisory committee, where he encouraged liberating the archive to more effectively support Earth Systems Science. He received the USGS Powell award and the USGS/NASA Pecora awards for his efforts.

As the Landsat got caught up in the commercialization argument, he participated in the dialogue. He expressed his concerns with the EOSAT experiment and business model pointing out the damage this was inflicting on the potential of the observatory. When Landsat was returned to government operations in 1992, he volunteered to serve on the Landsat Science Working group, and when NASA solicited for a Landsat Science Team, he was selected to serve as the Team Leader. When Congress mandated NASA conduct a \$50 million science data buy in 1997, NASA Stennis staff contacted him to conduct the science review of products offered by the commercial community. Although the Landsat Science Team had contributed substantially to the success of the Landsat Mission, it was disbanded in 2001 prior to NASA seeking data buy bids to provide Landsat-quality observations as a follow-on to Landsat 7.

He was approached by Resource21 to form a science team for them to support their data buy bid. Despite this input, which contributed to the design of the mission, the bid was not accepted. A decade later Landsat 8 was finally launched, also a decade after Landsat-7 had suffered a critical operational problem. Most recently Dr. Goward worked with Dr. Darrel Williams, his former doctoral student, retired NASA civil servant, and current Global Science & Technology, Inc. Chief Scientist, to propose a low cost, small satellite technology solution to support increasing time frequency repeat of Landsat observations to the NASA EV-2 program. The proposal was not selected. At the same time Dr. Goward and colleagues were innovating important new approaches to provide large region studies with Landsat for forest changes that have occurred over the last 25 years.

Over his career, Dr. Goward has attempted to maintain a balanced perspective between the scientific value of the Landsat mission and its contributions to economic activities in this contrary. He certainly appreciates how complex an issue this is but believes we have yet to embrace what is needed to successfully capture the potential on both sides of this discussion.

Chairman BABIN. Thank you, Dr. Goward.
And now I would like to recognize Dr. Busalacchi for your testimony as well for five minutes.

**TESTIMONY OF DR. ANTONIO BUSALACCHI,
PROFESSOR AND DIRECTOR OF THE EARTH
SYSTEM SCIENCE INTERDISCIPLINARY CENTER,
UNIVERSITY OF MARYLAND**

Dr. BUSALACCHI. Good morning, Chairman Babin, Chairman Bridenstine, Ranking Members Edwards and Bonamici, and members of the Subcommittee.

Prior to my coming to the University of Maryland 15 years ago, I was a civil servant for 18 years at the NASA Goddard Space Flight Center. While I was a lab chief at Goddard, I served as a 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 the Decadal Survey for Earth Sciences and Applications from Space being carried out by the National Academies of Science, 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 application communities for an integrated and sustainable approach to the conduct of the U.S. government’s civilian space-based Earth system science programs.

Before continuing with my testimony, I should note, though, that I’m speaking in my own behalf today. Nothing in my testimony should be construed as indicating anything about what the Decadal Survey Committee may recommend when a report is published in the summer of 2017.

If there’s one take-home message from my testimony this morning, it is the need to establish a series of best practices to guide future public-private partnerships for Earth remote sensing, drawing on the lessons learned from the past. So in this regard, and based on my own experience, the following are characteristics of a successful partnership between NASA and a private entity.

Firstly, the need to establish an appropriate insight/oversight model with a commercial partner. What worked well for the SeaWiFS Science data buy was one where NASA maintained insight, but not oversight, of the project. Next, to ensure the highest quality of the scientific data, NASA needs to have access to the algorithms and instrument characterization, access to, and ability to re-use the data, and establishment of an appropriate data archive. Turning data into information of value to both the 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, often combined with data from other sensors and platforms, and control how the data are archived.

Another important aspect is the 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, via development of a prototype system, or synthetic data sets, can contribute directly to engineering and system analyses. It can also optimize algorithms through competition. Such teams provide a conduit to the user community, and also provide timely engagement of the research community, which would rapidly expand the user base.

With respect to a successful public-private partnership, technical readiness is an important measure of what observation methodology may be ripe for transition. In the case of Earth imaging, as we've heard this morning, there's over six decades' worth of heritage on the design of such sensors. This has provided the opportunity for significant core competencies to be developed, as we've heard, in the private sector, thus enabling public-private 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 or observation, the greater the requirement for government involvement in order to draw on a wider base of expertise for sensor characterization, calibration, validation, science data processing, and re-processing.

Lastly, while obvious, it must be stated that the 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's little incentive for a public-private partnership. In the example of SeaWiFS, the cost to the government was reduced by Orbital Science's intent to sell the real time data to the commercial fishing industry. Transition across basic research, to applied research, to development of products and applications is not fast, and it's not easy. However, the extent to which this can be accelerated in support of a range of societal benefit areas, be they agriculture, transportation, fishing, land use, et cetera, will determine the non-governmental demand for the data, and potential cost savings to the government.

In closing, public-private partnerships offer an alternative and potentially less costly method to acquire Earth observations. However, with SeaWiFS as a guide, a successful public-private partnership may be realized only in limited circumstances, and only with the careful attention to the particular needs of both profit making entities and the science community. Thank you for your attention. I look forward to the questions.

[The prepared statement of Dr. Busalacchi follows:]

Exploring Commercial Opportunities to Maximize Earth Science Investments

Statement of

Antonio J. Busalacchi, Jr., Ph.D.
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National Research Council
and
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before the

Subcommittee on Space and Subcommittee on Environment
Committee on Science, Space and Technology
U.S. House of Representatives

November 17, 2015

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?

SeaWiFS³ 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.

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 MODIS⁴ 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 JPSS⁶ 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.

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, 2010¹¹).”

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

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

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.

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He has served extensively on National Academy of Science/National Research Council (NAS/NRC) activities, including as Chair of the Board on Atmospheric Sciences and Climate, Chair of the Climate Research Committee, Chair of the Committee on Earth Science and Application: Ensuring the Climate Measurements from NPOESS and GOES-R, as Co-chair of the Committee on National Security Implications of Climate Change on U.S. Naval Forces, and as a member of the Committee on Earth Studies, Institute of Medicine Committee on the Effect of Climate Change on Indoor Air Quality and Public Health, Committee on Assessing the Impacts of Climate Change on Social and Political Stresses, and Committee on the Assessment of NASA's Earth Science Program. Dr. Busalacchi currently serves as Co-Chair of the NRC's Decadal Survey on Earth Science and Applications from Space, and he also serves on the Intelligence Science and Technology Experts Group (ISTEG).

In 2014 he was elected as Chair of the American Association for the Advancement of Science (AAAS) "Section W" on Atmospheric and Hydrospheric Sciences as well as being elected as a Trustee to the University Corporation for Atmospheric Research (UCAR) Board of Trustees. Professor Busalacchi has received numerous awards and honors. Among these, in 1991, he was the recipient of the prestigious Arthur S. Flemming Award, as one of five outstanding young scientists in the entire Federal Government. In 1995 he was selected as Alumnus of the Year at Florida State University, in 1997 he was the H. Burr Steinbach Visiting Scholar at Woods Hole

Oceanographic Institution, in 1999 he was awarded the NASA/Goddard Excellence in Outreach Award and the Presidential Rank Meritorious Executive Award. He is a Fellow of the American Meteorological Society (AMS), the American Geophysical Union (AGU), the American Association for the Advancement of Science (AAAS), and in 2006 was selected by the AMS to be the Walter Orr Roberts Interdisciplinary Science Lecturer. As part of his broader professional interests Busalacchi builds on his family background and also provides a broad range of consulting services including wine education, wine list and wine program consulting, and viticultural weather and climate forecasting services, nationally and abroad via www.VinoVeritasLLC.com.

Chairman BABIN. Thank you, Dr. Busalacchi. I thank all of the witnesses for your testimony, and the Chair recognizes himself for five minutes.

Dr. Scott Pace, traditionally NASA's Earth Science Division focused on one-off research satellites to demonstrate technology in science. Recently, however, NASA was given responsibility for the Sustainable Land Imagining Program, and a number of NOAA's long term satellite observational requirements, including TSIS-1, the Ozone Mapping and Profile Suite, OMPS, and the JPSS-2 radiation budget instrument, and future ocean altimetry missions. How, if at all, do these new responsibilities represent a unique—represent unique opportunities for public-private partnerships?

Dr. PACE. Okay. Thank you, Mr. Chairman. Each one of these missions is somewhat different, and, as my colleague was saying earlier, need to pay attention to the particulars of each case, in particular finding, you know, non-government or non-NASA agencies who want the data. In the case of Landsat, at the risk of continuing the Rodney Dangerfield analogy, I think that the technical risks in providing that data tend to be the most well-bounded, and there are multiple non-NASA users. And that, given the right incentives, commercial entities could fund development tests and operation of those systems.

However, that option, I think, has been largely precluded by the intent of Congress, that NASA would develop the next Landsat satellite pretty much as a repeat of earlier satellites. And I would simply look at the NASA Appropriations Conference report for fiscal year 2015, which really precludes any sort of out of the box approaches to data collection. That's why I talked about the need for some sort of on ramp, or parallel activity, maybe revising the science data buy, or maybe looking at some more partnerships with NGA in each of these areas, and to not pre-judge what the outcome would be, but maybe have a competition through NGA, or through the SDB, and see what you get. I would suspect that the Landsat option would come in pretty attractively, but then there would have to be a robust internal discussion in the Congress as whether or not they wanted to have that on-ramp, or really—rather, they wanted to continue with the current appropriations language.

Chairman BABIN. Thank you, Dr. Pace. And this next question is directed to Dr. Scott and Mr. Schingler. According to the 2007 Earth Science Decadal Survey, an emerging source of data is the commercial sector. In the past, a program of Earth observations was associated almost exclusively with government managed or government sponsored projects. Today, commercial sources of Earth information are rapidly increasing in availability and scope. Commercial satellite systems are now reliable sources of high resolution Earth imagery, and commercial remote sensing companies have greatly expanded their offerings. In your opinion, where does the commercial remote sensing sector stand today, and how can the commercial sector fulfill civil government Earth observation needs? Dr. Scott, you first, and then Mr. Schingler.

Dr. SCOTT. So I'd say—I'll break the answer down into two parts. The first part is to leverage those data sources that already exist, bearing in mind not to break the business model. So we've talked a fair bit about where sharing of data can be bounded by licensing.

So, for example, sharing of data to the research community, but perhaps not in a way that undermines the commercial benefit broadly. We have such an agreement in place with NGA, where NGA has quite a degree of ability to share within the government, with coalition partners, with allies, but that does not undermine our ability to serve our other commercial customers with different licensing models. So it's possible for those to coexist.

Then I think the second part is to leverage the commercial sector to create data sources that might not yet exist, but which could be created cost-effectively, because the commercial sector is able to acquire systems and operate them in a manner that is typically more efficient than traditional government acquisition. And the best situation is certainly one where the commercial provider, if you will, lives in the house that it builds, where it leverages the same system to support government and non-government needs, and so the totality of its business is based on the success or failure of that system. So the incentives of the commercial provider are aligned with the government.

Chairman BABIN. Thank you, Dr. Scott. Mr. Schingler?

Mr. SCHINGLER. The decadal survey for Earth science was a great step forward, because it was actually the first time that it was done by the National Academies and Earth Science, so it really did provide a prioritized list of the data that needed to be collected, from a scientific basis.

Within that, they had a call for venture class missions, and—which, in my opinion, is one of the greater things that we could do in order to lower barrier of entry for new scientists to come in to understand our planet. However, the sensors were not there, the industrial base was not there in order to reach a price point at the time that the National Academies report was released. Today it's very different. You could actually see that launch access to space is still a major barrier, and part of NASA launch services, together with SMD, is helping to fund \$17 million for three new commercial nano launch capabilities and access to space. It's a really, really good step forward.

But when you combine those things together, you could think about a portfolio of different scientific activities, some of which bring about a rapid amount of capability, taking more risk, but at a much decreased cost. And then with that, that can then help smooth our future critical path into the future. Thanks.

Chairman BABIN. Thank you, Mr. Schingler. Now I'd like to recognize the gentlelady from Maryland—Ms. Bonamici, okay. I'm sorry.

Ms. BONAMICI. Thank you, Mr. Chairman. Thank you, witnesses, for your testimony. Dr. Pace, you said in your testimony that in acquiring commercial data, NASA should ensure it gets sufficient rights so that data sets should be—can be shared for scientific, non-commercial purposes. It should also ensure that it has sufficient insight into how the data were generated so that scientific peer review can independently assess conclusions based on those data. So Dr. Goward brought us some lessons from history. So how is that accomplished? Is that through regulation, or through really good negotiation? How does NASA ensure that it gets those rights, and that it has that insight?

Dr. PACE. I think it has been described, actually, by Dr. Scott that there are a wide variety of rights that you can buy. In some ways, the idea of purchasing data is kind of a misnomer. What you—you really don't buy a computer program. You buy a license to use that computer program. So the question is, what's the negotiation over the bundle of rights you can get? An NGA, of course, has a way of negotiating certain rights. So it becomes a competitive aspect, and there's a cost tradeoff. It becomes part of the make or buy decision for the government. So the government goes in and says, I want to acquire certain kinds of information, data, to do my public mission. I can decide to build a government satellite to do that at a certain amount of cost, sometimes more than what the private sector would do, but then I have more flexibility down range. Or I can decide to buy a bundle of licensing rights to go get the same sort of thing. And this is where having a large buyer, like NGA, can be leveraged, you know, for the benefit of the government.

So I think it's fundamentally a business analysis, make or buy, and then fundamentally it's a legal negotiation and a competitive process, and that companies should come in and be prepared to bid a range of activities. Now, if it's something like a decadal science priority, I would say that there be a high, high priority on having very deep metadata that you get because you're trying to do something at a very much cutting edge. There may be no commercial counterpart for that decadal science priority. And so then the question of build or buy becomes really of can the government do it more efficiently, or can a private sector party do it efficiently?

Ms. BONAMICI. Thank you very much. Dr. Busalacchi, for a public-private partnership that supports NASA's requirements for basic and applied research, how does that compare with a public-private partnership that could support NOAA's operational weather mission? When we're considering evaluating those public-private partnerships, what are the differences, and how would we evaluate those?

Dr. BUSALACCHI. Thank you very much. First, there's a clear difference between NASA research and NOAA operations. They're often seen as parallel, but there are significant differences. Let me draw on the NOAA operations example. In order to support numerical—operational numerical weather prediction, the demands of providing a forecast on time scales from minutes, to a day, or a couple days into the future, require those observations to be taken down, adjusted into the model, and those bits can actually then fall on the floor after they're used for supporting the numerical weather prediction.

Now, we've learned that those data do have value for other applications. However, in the case of NASA research, when you're looking at time scales from days, to weeks, months, and years, you're very concerned about the stability, the continuity, insight to the algorithms that you may not have because of proprietary reasons when dealing with the private sector. So there's a difference in time scale, and a clear difference in the need for stable, continuous calibrated and validated records on the research side.

Ms. BONAMICI. And that leads me to my next question, for Mr. Schingler and Mr.—and Dr. Scott. Many Earth science objectives

require long, stable, uninterrupted time series measurements. Can the commercial market support such a long term operation? With NOAA weather data, for example, it's important to have open, publicly accessible data so our—other countries will share their data with us, and the American public has access as well. So what happens if the U.S. buys data, and then can't share it? If NASA contracts out its Earth science work with a predictable, reliable funding stream, would the public-private sector accommodate requirements to make that data public?

Mr. SCHINGLER. So the commercial community can absolutely help to support time series measurements in a reliable and predictable way in no other case that our commercial customers demand it as well. So that is absolutely something that the community can do. When it comes to NOAA, and when it comes to the license around publicly available data, I think that needs to be incorporated into the business models of the companies.

So perhaps you could use an example of what we know in the aerospace community with GPS and selective availability. So there could be a downgraded version that is available to the U.S. Government that is bought, then made as open data, with then higher fidelity data for some of their commercial customers. So that is something that you can then coexist, and come up with a sustainable business model around, while you still actually create a public good, and provide that service to the government.

Ms. BONAMICI. Dr. Scott?

Dr. SCOTT. Well, in terms of data continuity, we've been providing data since 1999, which, relative to the Landsat program, doesn't go back to 1972, but for the commercial remote sensing industry, is certainly the longest uninterrupted record of continuous observation. I'll also mention, just as an aside, the commercial sector has put quite a degree of effort into a high degree of fidelity and calibration of that data, leveraging, in fact, a lot of work that NASA had done over the Landsat program.

In terms of open availability, I think open is—it feels very binary. It feels like it's either completely open, or it's not open at all. And, as Dr. Pace was saying, it's very analog. There's a wide range of gradation. I'll use for—DigitalGlobe as an example. We make data available to web portals, Google, Apple, and others, that you can download on your mobile device. You'd say, well, that's open. How does that not undermine the commercial market for DigitalGlobe's data? Because there are certain rights and certain limitations on the data that's available that mean that it's possible for us to, in a very granular way, enable data for different customers with different rights to meet their specific needs.

So I want you to imagine, for example, making data available that had rights for sharing for research purposes, but not for commercial purposes. Or rights that were available for sharing with other nations, but not for sharing for commercial purposes. So I—

Ms. BONAMICI. Thank you very much. My time has expired. Thank you.

Dr. SCOTT. Thank you.

Ms. BONAMICI. I yield back. Thank you, Mr. Chairman.

Chairman BABIN. Yes, ma'am, thank you. I now recognize the gentleman from Oklahoma, Chairman Bridenstine.

Mr. BRIDENSTINE. Thank you, Chairman Babin. I'd like to thank all of our panelists for being here. I was hoping maybe next time we could get a few more degrees on the panel. With all these doctors, for a second I thought I was in a hospital, but I'm glad I'm not in a hospital. So it's great to see all of you. Dr. Scott, I wanted to, number one, thank you for the service you've already given to this great country. You took great risk upon yourself, and created something that brought us to where we are today, which is why we're even having this discussion, so thank you for your service, and all you've already done.

Dr. Goward, I wanted to address your comments earlier. I read your testimony, and I had a different takeaway from what I just heard. And I wanted to see if maybe I could have you maybe enlighten us a little more about what your thoughts are going forward. One of the things I read is—it says today, with the maturing of new sensor and satellite technologies, the opportunity exists to fly at least four Landsat observatories at the same total cost as a single satellite which uses the traditional technology of Landsat-8. So when you talk about these new technologies, it sound—your testimony that I read sounded a lot like Mr. Schingler. Can you share with us your thoughts? Do you believe we can move towards a Landsat kind of commercial capability? Can you turn on your microphone, please?

Dr. GOWARD. Thank you. I'm not sure it would be commercial. I mean, that's really outside of my purview in many ways. But, my former student and colleague, Darryl Williams, and I put together an EV-2 proposal through Global Science and Technology, and in that we worked with Surry Satellite, and it's a U.S. based company at this time. And we did a proposal which showed that, for about \$130 million, we could build a prototype system. Wouldn't be fully complimentary with Landsat, but sufficiently to supplement and compliment Landsat. That's substantially less than what this last—Landsat-8 has cost us. GST then went on to do further work with Surry. In a fully complementary Landsat mission, was able to demonstrate that, for about a quarter of a million dollars—quarter-million—\$250 million they could build a fully complementary system.

It's my view that we should give this a try now, and get that technology out on the table, because, again, from our scientific experience, I don't believe that the commercial potential of the Landsat mission will be realized until we get, as my colleague to the right mentioned, daily repeat coverage.

Mr. BRIDENSTINE. Right. Okay.

Dr. GOWARD. The land dynamics just happen too fast, and you don't see it every 16 days, when clouds block you at least 50 percent of the time.

Mr. BRIDENSTINE. Okay. I'm running out of time here. I wanted to move to Dr. Pace. You mentioned in your testimony that the Earth sciences missions have—the demands have grown, and the requirements have grown, and yet there are opportunities where we can share the cost because there are non-NASA customers, potentially. And you mentioned Landsat is one of those places where

we could do commercialization, but then you mentioned that it was precluded by Congress. I'm very interested in this. What did Congress—why did Congress preclude this?

Dr. PACE. Well, my understanding is, if I read the NASA Appropriations Conference report, it states, "The Committee"—"Conference does not concur with various Administration efforts to develop alternative out of the box approaches to this data collection"—referring to Landsat—"whether they are dependent on commercial or international partners." And so essentially this said, build another Landsat satellite similar to what you've already been building. And I have a sense of *deja vu* with this because I was the guy at the Commerce Department who was told to get Landsat out of the Commerce Department at that time, so I wasn't very popular with my other agency colleagues.

One of the things that we looked at were alternatives for LightSAT or SmallSAT versions of Landsat in 1992. We were taking advantage of some SDI technologies that had come out of Livermore Laboratories and other places, and so there were theoretical designs, and they were all just that, theoretical, but for LightSAT versions of Landsat that Dr. Goward was also talking about. And so it strikes me that today, given the greater design maturity and experience we have with small satellites, that we should go back and be looking at more innovative ways of doing things. The reason we wanted to look at SmallSATs back then is we felt that cost growth would be a problem for any agency that took over Landsat. And so that's why I said in my testimony that if we simply continue with only the traditional practices, that is actually going to be more risky than having some innovative options in the portfolio that could lower costs in the longer term.

Mr. BRIDENSTINE. Okay. That—and I'm out of time, Mr. Chairman, but as far as the appropriations, I guess, Conference report, that language is unfortunate. I don't think that necessarily reflects the view of a lot of people that serve on this Committee, on both sides of the aisle. So I need to delve down into that a little bit more. Maybe, Mr. Chairman, if we could do a second round, I'd appreciate that. Over to you. Thank you.

Chairman BABIN. Thank you, Mr. Chairman. I'd like to now recognize the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chair. And I'd be happy to defer to the Ranking Member from Maryland, if she would prefer that.

Ms. EDWARDS. Thank you very much.

Chairman BABIN. Sorry about that.

Ms. EDWARDS. Thank you very much. Just a little confusion here, just moving around. I'm curious—OSTP's national plans for civil observation includes an action entitled Explore Commercial Solutions, where federal agencies are actually tasked with identifying cost-effective commercial solutions to encourage private sector innovation while they preserve the public good nature of Earth observations. In particular, agencies are asked to consider a variety of options for ownership, management, and utilization of Earth observation systems and data, including commercial data buys and commercial data management. In developing such options, agencies are to preserve the principles of full and open data sharing, competitive sourcing, and best value in return for public investment, and I'm

curious as to the viewpoints, if we could, quickly, should be the first steps in implementing this kind of guidance from OSTP. Starting with you, Dr. Pace?

Dr. PACE. Well, I think one of the things that ought to be looked at is—look across all of the agencies that are involved in this sort of remote sensing. This means looking at what NGA is doing with its strategy, look at what NOAA is being asked to do, look at what NASA's looking to do. So don't look at it as simply an agency—single agency only sort of thing. It's really across the administration.

And then you should be able to see, what portfolio mixture am I doing? Am I just—what things are being done as large traditional satellites? What areas do I have innovative smaller satellites, and what areas do I have a mixture of small data buys, or licensing, pilot programs? So I'm not trying to say what those number ought to be. I'm saying there ought to be a portfolio, and then there ought to be a discussion within this Committee, and within both sides of the Hill, as to what the right amounts of effort ought to be in those areas. But you ought to have a mixed portfolio, not just a single one.

And so I don't think that the OSTP direction is quite being followed at point. I also don't think that the decadal survey recommendations, to look at more innovative sourcings, are being followed. And I think that NASA in particular is being burdened by large operational ongoing missions that—there's all kinds of good reasons why they're there, lack of appropriation allocations for NOAA, problems with the 302(b) allocation, all those sorts of things. But nonetheless, NASA is getting more burdens than simply you would expect from its decadal science queries.

Ms. EDWARDS. Dr. Goward, do you have an opinion about this?

Dr. GOWARD. Thank you. Just thought of four general guidelines in my experience over the years is—as Dr. Busalacchi had mentioned, insight versus oversight in private-public partnerships is really critical, otherwise private industry gets hampered in innovating in the—in their work. But from the other side, private industry has to be willing to participate in arrangements where the observations are available for no cost distribution. Particularly for the Landsat mission we've gone from practically no usage of the historical record to usage that's in the millions over the last 2 to three years because USGS has been willing to provide low cost—no cost access to the data record.

Honestly, one of the limitations on—was that they were not allowed to compete in the applied commercial marketplace, and this was a serious problem for them. The—that company was unable to really build on their capacity to develop the commercial marketplace. They were prevented from doing so.

Ms. EDWARDS. In the time that I have remaining, do any of the other witnesses have an opinion about OSTP's guidance, and how we can begin implementing that guidance?

Dr. SCOTT. I'd say one of the first things to do is look at what the industry is both doing and capable of doing. There's often a tendency within government to make assumptions about the industry that are, in fact, not founded in fact, and a good place to start would be to reach out to the industry and find out what the indus-

try thinks, what the industry is doing, what the industry is capable of doing.

Ms. EDWARDS. And Dr. B, because I am butchering your name.

Dr. BUSALACCHI. That's fine, I'm used to it. So I've already spoke to the issue of the heritage of the methodology. In the case of SeaWiFS, with respect to data access challenge, in order for Orbital Sciences to market ocean color data, NASA did not have free and open access to the data, and overall this data access arrangement worked well for research. The researchers had to register and verify that they were only using SeaWiFS data for research, and not for commercial purposes. And even though most of the research with SeaWiFS was done in delayed mode, we even still, within the rights of the data license, had access to the data in real time for certain cruises.

So, going forward, any public-private partnerships need to develop a cost model based on data latency, archival, access, and resolution. It's going to be really issue to sort of—really important to tackle those issues.

Ms. EDWARDS. Thank you very much, and I yield the balance of my—well, I don't have any time, but I yield it anyway.

Chairman BABIN. Thank you, Ms. Edwards. Let's see. I'd like to recognize the gentleman from Arkansas, Mr. Westerman.

Mr. WESTERMAN. Thank you, Mr. Chairman, and thank you to the panel for being here today. Dr. Goward, you talked about Landsat being the Rodney Dangerfield, but, you know, I would like to give it maybe a little bit of respect today. Having worked in the forestry industry, I've seen how the imagery can be used. You know, in all—we've had developments in the analytics, being able to look at the images and gain more from the images. You know, in a wintertime photograph you can tell coniferous trees from deciduous trees. And then—now, through spectral imagery, you can look at the different signatures of the colors of the leaves, and get a species distribution through it.

So I know that the analytics have advanced, but how would you say the image resolution and quality of data has changed for Landsat over its 43 year history? And maybe, just briefly, Landsat-1 versus Landsat-8?

Dr. GOWARD. The changes have been subtle. The changes occurred between Landsats 3 and 4, when we went from one type of a sensor, MSS, to thematic mapper, TM. And then with the LOI on Landsat 8, a number of changes occurred. Additional bits of data to characterize illumination conditions, narrowing of the bands to increase avoidance of atmospheric contamination.

So they may be subtle, but they get critically important information that allows us to more and more reliably evaluate forests, agricultural production, other features that we just simply get better at as we refine our instrumentation.

Mr. WESTERMAN. So we've got a long record of continuous and comparable observation that has allowed users to document changes to the land surface and other features over decades. What are the advantages and disadvantage of—and disadvantages of deploying Landsat instruments on other satellites, whether government or commercial, instead of recreating the same Landsat satellite as the one vehicle for U.S. moderate resolution land imaging?

Dr. GOWARD. I see no reason not to deploy an equitable instrument on a variety of platforms. The things you have to be careful about are the orbital patterns, whether you're in a sun synchronous, or in a solar variant observation condition. But you're certainly not constrained to a single platform.

Mr. WESTERMAN. So you think we can maintain the aspects of the data continuity with different platforms?

Dr. GOWARD. No, absolutely, and it's more that the detail level of the instrument characteristics is critical.

Mr. WESTERMAN. Okay. So the cost of Landsat-8 was about a billion dollars, and the Administration is now preparing to develop Landsat-9, I think the last I saw a 2023 launch for Landsat-9, which is essentially a clone of Landsat-8. Is there a rush to develop Landsat-9, or does the government have the time to evaluate all options for satisfying these data requirements? And what would you recommend NASA do?

Dr. GOWARD. It's an interesting problem. The design life of Landsat-8, from an engineering point of view, is five years. So that, by the time we get to 2023, we're over ten years. Now, do we suffer a failure in between time? I don't know. We certainly had had problems with Landsat-7 early on, and it could happen again. So are we in a rush? Should be, because we should move that timeline for the next launch to an earlier date, if at all possible.

Mr. WESTERMAN. So how many Landsats are we getting imagery from now? Are there still two—

Dr. GOWARD. Still two.

Mr. WESTERMAN. And what—those are eight and—

Dr. GOWARD. And 7.

Mr. WESTERMAN. Okay.

Dr. GOWARD. And 7, of course, has a partially functioning mirror system.

Mr. WESTERMAN. Okay. And with that I'll yield back, Mr. Chairman.

Chairman BABIN. Thank you, Mr. Westerman. Now I'd like to recognize the gentleman from Virginia, Mr. Beyer.

Mr. BEYER. Thank you, Mr. Chairman, and I would like to thank both Chairmen and both Ranking Members for putting this together. And thank all of you for coming. It's been fascinating.

Mr. Schingler, a—probably a stupid question, but you mentioned that you have the—100 doves up in a single sun-synchronous orbit. Are these spaced all around the globe, in the orbit itself, and is it really just a single orbit, or a single orbit for each dove?

Mr. SCHINGLER. Yeah, let me clarify. So over the last 2-1/2 years we have launched 101 satellites on nine different rockets. All of those have been as secondary payloads, and the majority of them have been through the International Space Station. And the International Space Station is in a 52 degree orbit, so it is not in a sun-synchronous orbit. Over the next 12 months we have a number of launches, including one that is a dedicated rocket, that is going to our ideal orbit, which is a 475 kilometer sun-synchronous orbit. And that one launch, in and of itself, will be able to allow for us to have daily coverage.

And the way that that works is we distribute the satellites along track in one particular sun-synchronous orbit, and as the Earth ro-

tates underneath it, our satellites act together, kind of like a line scanner, in order to image the entire surface of the Earth.

Mr. BEYER. Line scanner's a great image, so thank you—and the size of the satellites?

Mr. SCHINGLER. The size of our satellites are five kilograms. They're in the 3U form factor, so it is—one person can pick it up.

Mr. BEYER. Yeah, very cool. And, Dr. Goward, your last recommendation said NASA and the U.S. private sector need to move away from increasingly expensive single satellite builds towards lower cost, high temporal repeat Landsat class observatories, et cetera. Is this what Planet Labs is doing, or is this what DigitalGlobe is doing?

Dr. GOWARD. What Planet Labs and DigitalGlobe are doing are not the same thing. What we're really talking about, for a Landsat system, is one that covers four different parts of the electromagnetic spectrum, and some of those require a more complex platform than what, for example, Planet Earth will be flying. And when I mention the lower cost SmallSAT alternative, we're talking about more on the order of three to 500 kilogram satellites, rather than five kilogram.

Mr. BEYER. Okay. Great, thank—yes, Mr. Schingler?

Mr. SCHINGLER. Yeah, absolutely, the Landsat platform is really quite exquisite in its spectral capability. And that is something that we have longitudinal information over the last 42 years, and want to continue moving forward. I think part of the concept is it may be possible to launch an instrument that does not do all of the spectral bands in one satellite, but instead you can have a couple of different satellites that then focus on the phenomenology that we want to continue as a global community with Landsat.

Mr. BEYER. One of the things I've been impressed by today with—including all these degrees, as Chairman Bridenstine noticed, is how many of you have moved back and forth from government to private sector. Dr. Pace, do you have any concern, with your NASA and your private sector perspective, that there would be a loss of in house expertise as we outsource more and more to the commercial sector?

Dr. PACE. That's a great question. I think that's actually really central to thinking about what do we want NASA to do to be a smart buyer? I think NASA should always have one or two spacecraft builds in house that they do themselves to make sure they have that hands-on expertise. At the same time, I think that NASA is comfortable and—with the idea of buying—and relying on the private sector, and doing commercial data buys.

And I think, as NASA has been asked to do more and more missions without really an increase in its top line, I think it's going to become more incumbent on them to find ways of partnering with the private sector. So I would first say make sure they have expertise in house at places like Goddard, but also make sure that they start relying more on the private sector to acquire the data. And, as Dr. Scott said, the best way to do that is to ask industry. Too often we can assume what industry can do. And it's perfectly possible for industry not to be able to meet requirements at a certain point in time, so it's always important to have a backup plan. Having a primary plan of, you know, a conventional spacecraft, okay,

but make sure you also have a backup plan, or an alternative, doing something more innovative. And, really, I think the agency should be doing both.

Mr. BEYER. Great, thank you. Dr. Busalacchi, I only have a minute, but you were deeply involved in SeaWiFS. Was that cost effective? And using Orbital Sciences, was there added value gained from partnering that perhaps offset the extra cost?

Dr. BUSALACCHI. Well, SeaWiFS was a grand success in terms of the quality of the science data we got, and the cost to the government was actually less as a direct result of the private sector data buy. Now, whether or not Orbital Sciences made a profit, I'm not the one to speak about that, in Virginia, for example. But, again, it was a grand success from the science point of view.

But what we don't realize, oftentimes, is how important the engineers at Goddard—the role that they play. Even though this was technically a data buy, there were a number of challenges that came up. The mission was delayed by four years, and Goddard engineers, in the end, provided considerable support on the engineering side for power system, altitude control, navigation system, component quality. We had a very good working relationship, but the point was—is that—as opposed to a number of the topics here this morning, there was not a lot of heritage in the instrument. There was the prior coastal zone color scanner, but beyond that, there was a novel lunar calibration, so there was really the need for expert engineering support from an organization like Goddard.

Mr. BEYER. Great. Thank you very much. Thank you, Mr. Chairman.

Chairman BABIN. Yes, I'd like to recognize the gentleman from Colorado, Mr. Perlmutter.

Mr. PERLMUTTER. Thanks, Mr. Chairman, and to Dr. Scott, long time no see. Appreciated the tour last week of DigitalGlobe. And I guess my question—I'll start with you. You've got this giant library of information. Who gets access? Who curates it? How does anybody figure out all the stuff that's in there?

Dr. SCOTT. So we have generated about 100 petabytes or so of data. It's accessible in the cloud. It's catalogued by an increasing amount of metadata, starting with just when it was collected, but growing to include a lot of information about what's actually in the image. And we've exposed that to our customer community via something we call a geospatial big data platform, which is fundamentally about not trying to take these huge data boulders and say, you know, here's 100 petabytes of data, good luck finding a place to put it, instead enabling people to access data in the cloud with a set of algorithms that are wrapped around it to enable exploitation, and a growing ecosystem of partners who contribute those algorithms to enable the exploitation.

Mr. PERLMUTTER. So if I wanted to see something involving the soils in some country in Africa, how do I get that information to you, and then how do you provide me that slice of information?

Dr. SCOTT. So there are a couple of ways of gaining access to that. If you're interested in viewing the data, just looking at the data, there are web services where we expose that data to you over the web. If you're interested in performing analytics, you can bring your algorithms, or use algorithms from one of our partners, like

Harris, who offers the ENVI toolkit, the image processing toolkit, and perform that processing in the cloud. We have a set of application program interfaces, as well as user interfaces, that allow you to search for what's available in that particular region, and then drop that data into your Amazon S3 bucket for subsequent processing.

Mr. PERLMUTTER. I guess what I'm—and I appreciate that. So you—DigitalGlobe—and to the other panelists, please jump in if you want—we're accumulating lots of information out there. And we don't know all the potential users of that, and precisely what they want to do with it. So if I am the United States Government—let's say I'm the Air Force. I pay you some certain fee for access to all of it, any time I want it, and then some other user of the library may have a much more limited cost, and, you know, library card that allows just access to certain things. Is that how it works?

Dr. SCOTT. I think that's a great model, actually. It's sort of a customized library card with rights that are consistent with how you intend to use the data. We support a range of business models. Some of those business models involve the actual delivery of data. Other business models involve—you get a library card for data analytics, and we receive our compensation in any of a number of ways, some of which are revenue share based, some of which are subscription fee based.

Mr. PERLMUTTER. Okay. So to all of the panelists, I mean, if there were one or two things that we, as members of Congress, could do to make sure that the technology that you all are developing, whether it's on the information side, or flying the satellite side, or the optical pieces, what could we do, maintaining security for the nation, yet allowing you to continue to grow the commercial side of this? Mr. Schingler.

Mr. SCHINGLER. So I think the first thing is we should figure out a way to relatively quickly get access to the commercial capability that's there, and to engage in a dialogue to really understand more—not just what the product is, but the capabilities of industry. That will help to inform strategies around procurement, and other things, into the future.

And secondly is—for things into the future, we should look at other transactional authorities, which do allow for the commercial entity to continue to build their commercial service, while relatively quickly sell a capability to the U.S. Government.

Mr. PERLMUTTER. Okay. Thank you. Dr. Pace?

Dr. PACE. I would add that we should probably be looking beyond just the initial data acquisition and the satellite side itself, and to think about where could commercial providers be part of the data archiving and processing, analysis function in the cloud. That is not something which is a government unique function. And there's also systems where commercial users could share, you know, the same hosting infrastructure, and that's whole other market, you know, in and of itself. It's just data. It's not particularly specialized.

The second thing I would mention, this is probably a subject of a different hearing, is making sure that NOAA's commercial licensing and regulatory process responds to the changes in technologies in markets that have been going on. The regulations that were

written in the early '90s really, in many cases, have become a bit outmoded. There's a lot that's really good, but there's a lot that's really largely irrelevant today, and I think that kind of regulatory responsiveness is a subject that the industry needs.

Mr. PERLMUTTER. Thank you, and I yield back to the Chair.

Chairman BABIN. Thank you. Now we're going to go back through for a second round of questions, and we're going to limit this to three minutes, if that's okay with everyone.

So my first question would be to Dr. Pace. In your testimony you mentioned that there's a need to protect the electromagnetic spectrum used by remote sensing and GPS. Now, if you would, please explain in more detail to the Committee.

Dr. PACE. Well, sir, for example, remote sensing is crucially reliant upon things like GPS to provide the actual location of the data. So if there's interference with GPS, there's interference with the remote sensing industry.

Chairman BABIN. Uh-huh.

Dr. PACE. There's also great pressure on all space spectrum by commercial communications. Everybody understands the importance of mobile broadband, the importance of that to the economy and growing the economy, but also there are unique functions that are under great pressure. One area in particular that's come up recently, and I'm sorry to use the phrase, six to nine gigahertz. There's some high frequencies that are being talked about for—in a Senate—on the Senate side, and this incorporates—covers a lot of microwave sounders that are used by multiple weather systems. And you can't move to other areas. The water molecule doesn't vibrate in some places. It's not flexible. And so I would suggest paying attention to spectrum as an underlying need of the industry, particularly for critical sensors that really can't be moved anywhere else.

Chairman BABIN. Thank you. And then this would be a question for Dr. Goward and Dr. Pace. Does the U.S. Government have a requirement to maintain one or two Landsat satellites at a time?

Dr. GOWARD. Undefined.

Chairman BABIN. Undefined?

Dr. GOWARD. Um-hum.

Chairman BABIN. Okay. That answered that. How about Dr. Pace? Same thing?

Dr. PACE. Nothing to add. It's—that's been part of the long story of Landsat.

Chairman BABIN. Okay. And then, real quick, all—in the next ten years, what major developments will be made commercial, remote sensing, and could these developments be used by NASA to improve their imaging efforts, or decrease the cost of remote sensing to the government? And if one of you would be glad to answer that, I would appreciate it. Dr. Scott?

Dr. SCOTT. Well, I think there are a number that have already been made, and this may actually be relevant to one of the earlier questions. Our most recent satellite launch, WorldView-3, incorporates 16 spectral bands of high resolution data, plus an additional 11 spectral bands of 30m resolution atmospheric data. And that was done leveraging technology that had been developed for the Landsat program, but at a very small fraction of the cost of a

Landsat satellite. That's just an example of the sort of innovations that are happening in the commercial sector that I would encourage the government to understand better in making its future decisions.

Chairman BABIN. Okay. Thank you. I would like to recognize Mr. Perlmutter again, from Colorado.

Mr. PERLMUTTER. Can I pass to Mr. Bridenstine as I'm collecting my thoughts here?

Chairman BABIN. Certainly.

Mr. PERLMUTTER. Okay.

Chairman BABIN. I want to recognize the gentleman from Oklahoma, Chairman Bridenstine.

Mr. BRIDENSTINE. So you're giving me all three of your minutes? Is that what's going on here? No, I'm kidding. I'll take my own three minutes. Thank you, Chairman, and Mr. Perlmutter. A couple of thoughts I had. You mentioned, Mr. Schingler, the exquisite spectral bands and capabilities from Landsat, and maybe that's not your area of expertise, but you could have a distributed architecture, or disaggregation, where you could have different satellites doing different things.

I heard, you know, Dr. Pace talk about—in his testimony he talks about maybe not commercializing Landsat, but using other sources to gather data. Is it possible, when you think about Landsat, and the commercial opportunities that are out there right now, can we gather similar data that would be useful, given the exquisite spectral bands that Landsat uses? Can commercial provide a resource in addition to Landsat, Dr. Pace?

Dr. PACE. Yeah, I think it can, and I think it would make for a robust series. Landsat data continuity is one of the precious things that the science community has, and rightly wants to guard, so having additional satellites has been mentioned. The idea of a single Landsat was never the original idea. It was always to have this kind of continuous observation. That, to me, sounds like a service that could be provided, with maybe government as a foundation, but with complements from the private sector in a way that, I would argue, is analogous to what's been talked about with GPS radio occultation.

Mr. BRIDENSTINE. I noticed that in your testimony, and thank you for bringing that up. I was not expecting that, but that's something we've worked hard on this Committee to have, radio occultation move alongside the other great capabilities that are being provided by NOAA, to move alongside it. And we've actually carved out some funding in our bill here on this Committee to make sure that NOAA could purchase that data. And, of course, working with Dr. Voles and Admiral Brown on those capabilities has been a great experience.

One last thing with my last 50 seconds, and maybe this is a question for Dr. Scott, we heard Dr. Pace talk about consistency in the regulatory framework coming from the Department of Commerce, coming from NOAA. Of course, that's critically important to this kind of industry. You make investments, and those investments are for your shareholders. At the same time, you're signing up contracts. When those regulations change in midstream, that can have negative consequences. Can you share with us if there's

anything we can do to ensure that there's—maybe we can, maybe we can't, but how does that affect you, as a business owner?

Dr. SCOTT. So when you build satellites that take a few years to build, and operate for a decade or longer, and have invested billions of dollars in the course of doing that, the stability of the regulatory environment is absolutely essential. You need to know, and your customers need to know, that they can rely on continuity of service, and that there won't be variability subject to essentially the whim of a government agency.

We've been fortunate that we have enjoyed, to date, an environment where, while it has not necessarily been as forward leaning as we would like, it's been stable. The ability of that regulatory environment to, instead of react to, but rather enable industry to anticipate market needs, that's something that we would like to see change. The pace of technology is moving far faster than the regulatory environment that was conceived back in the 1990s can remotely keep up with. And that's really one of the biggest impediments in the industry going forward.

Mr. BRIDENSTINE. Thank you. Mr. Chairman, I yield back.

Chairman BABIN. Yes, sir, thank you. Now I'd like to recognize the gentlewoman from Maryland, Ms. Edwards.

Ms. EDWARDS. Thank you, and I'll be brief. I'm just curious to know if there are some markers that can help us determine when and if NASA should use public-private partnerships for data collection. Is there, you know, some—one point, or—and then how should they be evaluated? Because I think we've gotten a handle on how we evaluate NASA driven, internal driven projects. How do we evaluate public-private partnerships? And if I could start with Dr. Scott, to Mr. Schingler, to Dr. Busalacchi in that order, and do it as quickly as possible. How to determine when and if, and how to evaluate them?

Dr. SCOTT. Probably the simplest phrase is start with asking. So start with exposing to industry what the needs are, and at the same time, engage in a dialogue with industry to understand what the capabilities are. One of the reasons why we have historically been able to acquire satellites very cost-effectively is that we approach the problem from both ends. We approach it from the standpoint of what is the technical capability, and then what are the business needs and the business opportunities? And we look for the intersection of those, as opposed to approaching it unilaterally from one side and say, well, you know, here's what we want, never mind the fact that it's nearly impossible to achieve it. We look for the intersection.

Mr. SCHINGLER. So for when to evaluate it, or for when to approach public-private partnerships, I think you first do need to evaluate it first, before you get into a complex arrangement between industry and government. And that evaluation, just exactly as Dr. Scott is saying, should be based on the service as it is today, and the direction of where it's going. And it may not be from the traditional requirements driven approach, but more of a capabilities-based approach. And that the assessment of the data shouldn't be necessarily taken by itself, but actually in conjunction with other data assets that are already there.

Dr. BUSALACCHI. So by forming points, as I mentioned, heritage, NASA's very good at assessing technical readiness, what is the reduced cost to the government, and what is the market demand in the commercial sector, and then evaluating what is the elimination, or reduction, in the financial and operational risk, what is the increased efficiency to be had, and what is the reduction in the fixed cost? I say those five main things can be evaluated.

Ms. EDWARDS. Thank you. 25 seconds to spare, and I yield.

Chairman BABIN. Thank you. Appreciate it, Ms. Edwards. And I'd like to recognize the gentleman from Colorado.

Mr. PERLMUTTER. Thank you. Thanks, Mr. Chairman. Dr. Busalacchi, just a question, and congratulations, I think, are in order for you to co-chair the decadal — you know, I've got to tell you, before I ever got on this Committee, I never heard the word decadal before, and I never was quite sure—apparently it's every ten years. It doesn't have anything to do with decay, does—

Dr. BUSALACCHI. No, but our report will be done in much less than a decade.

Mr. PERLMUTTER. All right. So my question to you is, as a co-chair with Dr. Abdalati, from the University of Colorado, by the way, are you going to be focusing on how the data's collected, or what types of data are collected, or both? I mean, can you share what your focus of the committee's going to be?

Dr. BUSALACCHI. So I'm not being facetious, it is all of the above. It will be looking at what census—or what missions where in the queue from the previous decadal survey that have yet to be realized, what new science and applications may be possible going forward, and, as we've been hearing here, what role can the private sector play, and what are the new technologies? Just right now the academy is having—spinning up a report that will be out before our report on CubeSATS. And so I fully agree with Mr. Schingler, access to space is a key issue, and if we could lower down the cost to access to space, the potential is there for these CubeSATS to be up there, and really change sort of our approach. So, again, short answer is yes to all of, existing science, new science, new technologies, and commercialization in the private sector.

Mr. PERLMUTTER. Thank you, Doctor, and I'll yield back to the Chair.

Chairman BABIN. Thank you, Mr. Perlmutter. I want to thank the witnesses for their testimony, and the Members for your questions. The record will remain open for two weeks for additional written comments, and written questions from members. And with that, this hearing is adjourned.

[Whereupon, at 11:59 a.m., the Subcommittees were adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. Scott Pace

Pace - 4 Jan 2016

Questions submitted by Rep. Brian Babin, Chairman, Subcommittee on Space

1. How should government agencies like NASA and NOAA measure success when it comes to public-private partnerships?

A. The term public-private partnership (PPP) should be used cautiously and rarely for U.S. government efforts. The term is really a European one that can take many different forms of government and industry entanglement, including forms that would be considered inappropriate (e.g., national champions, government equity ownership, direct subsidies, etc.) in the United States. I would suggest using terms such as “government/industry cooperative efforts” or even “government/industry risk sharing” to distinguish European-style PPPs from U.S. options such as the use of Space Act Agreements or Other Transaction Authorities.

The primary measure of success for government-industry cooperative effort should be whether public benefits, consistent with the mission of the agency, are being provided for the least cost of public funds. By least cost, I mean in comparison to traditional government programs for developmental items or the direct purchase for non-developmental items. In addition, the term “cost” means not just direct federal outlays, but any risks created by the cooperation such as future taxpayer obligation, loss of intellectual property rights, effects on in-house government expertise, creation of monopoly power, and backup plans in case of business failure.

Choosing to execute a “partnership” can be similar, but not identical, to a private sector business decision on whether to “make” in-house a needed capability or to “buy” it from an outside source, *i.e.*, out-sourcing. The difference for an agency is that its highest priority is to carry out authorized missions using specifically appropriated funds and not necessarily to turn a profit on public funds. (While NASA and NOAA are not economic development agencies, the Congress can add criteria such as local economic or industrial development and meeting foreign competition.) If an activity is truly profitable, with private resources and private demand, then it is questionable as to whether the government should be involved in the activity at all. Foreign governments may make different decisions for their activities, but in the United States, it’s generally accepted that agencies should not preclude or deter potential private space activities except for compelling reasons of public safety or national security.

a. How can we, as Congress, know when a public-private partnership has worked?

A. The first things to look for are whether the agency is seeking to allocate more resources to the cooperative effort, whether private parties want to continue or expand the program, and whether independent management reviews (*e.g.*, Inspector Generals, General Accountability Office) are concluding that the partnership is well run with cost and schedule targets being met. With regard to outputs and outcomes, since public goods are the primary goal, independent technical experts would be needed to assess agency claims, such as studies by the National Academies. The latter would be particularly appropriate for assessing the technical results from NASA and NOAA programs.

2. You are currently a member of NOAA’s Advisory Committee on Commercial Remote Sensing (ACCRES). In this capacity, you have unique insight into the opportunities and

challenges facing the space-based remote sensing industry from a regulatory and legal context. What critical issues facing the U.S. private space-based remote sensing should we, as a Congress, be aware of from a regulatory and legal context, and how, if at all, does that impact the ability to form successful public-private partnerships?

A. The United States Government is unlikely to have successful cooperative projects with U.S. firms if it does not have a supportive regulatory environment. The United States has been a leader in both technical and regulatory aspects of commercial remote sensing, but is facing increasing competition abroad and bureaucratic barriers at home. These challenges are the result of increasing technical change and globalization in which existing regulations and process are outdated and unresponsive. These conditions are deterring innovation and in some cases causing U.S. firms to consider moving their operations overseas.

NOAA's current regulatory resources are inadequate to keep up with changes in remote sensing technology and constellation architectures. Instead of a few satellites and a few ground stations, the global market is moving toward high numbers of satellites, globally distributed ground stations, and new sensors that pose new and unique problems for interagency licensing review. NOAA is trying to do too much with too little and it needs to update and streamline its licensing process as well as add additional human resources. NOAA's understandable attention to near-term urgent actions is crowding out out time to think and plan for more fundamental restructuring of the licensing process. This includes orderly progression towards a larger budget and, as mentioned above, additional staff to meet new and increasing demands.

New licenses are taking too long to review and approve, creating delays and uncertainties for U.S. industry while foreign competitors seek to fill the vacuum. The most infamous example of regulatory indecision was the loss of U.S. leadership in commercial space-based radar to Canada, Germany, and Italy. While one can argue that those countries provided industrial supports that the United States would not, it is also true that regulatory opposition and uncertainty bought crucial time for those competitors to come to market. NOAA and the Department of Commerce have authorities and processes to create relief from impractical regulatory enforcement actions, such as the need to physically visit ground stations each year. NOAA should be allowed to shift resources from enforcement and inspection missions to a verification and complaint-driven inspection system to manage compliance risks.

In general, despite supportive policy statements over multiple Administrations, the United States Government has not been leaning forward enough in the licensing of capabilities outside of familiar electro-optical imagery. Regulatory practice has not followed the policy statements. It would be helpful to make clearer that the burden of evidence for denying a U.S. license should be the demonstration of a clear potential harm to national security, public safety, or U.S. international obligations – in short, license applications should have a presumption of approval unless NOAA receives clear, documented evidence from its interagency reviews that harm would occur as result. In the licensing process, agencies should not be asked to judge the economic value or viability of a commercial capability in order to balance against other interests. (As a separate matter, agencies may consider economic factors as part of decisions to participate in a cooperative effort with private commercial remote sensing firms.)

3. The last time Congress updated the statute governing the regulation of private Earth remote sensing space systems was in 1992. That's over 20 years. Do you have any opinion as to whether the legislation needs to be updated?

A. Yes, the legislation does need to be updated. The technologies available today are different and competition is more global. The United States needs to be able run faster, not hope that other will be slow. However, as a first step, I would suggest a review of existing Part 960 regulations on “Licensing of Private Remote Sensing Space Systems” and see how much can be done through the Administrative Procedures Act. The Congress would then be in a better position to know what specific and targeted legislative changes would be needed.

Some examples of regulatory improvement that should be considered are:

- Require express disposition of a request – whether positive or negative – by a date certain and avoid delays merely for agency convenience.
- Prohibit inaction on a request because inaction is tantamount to a denial.
- Delete references to the “processing” of data as an over broad regulatory overreach.
- The definitions of *Significant or Substantial Foreign Agreement* (also referred to in the regulations as *foreign agreement* or *agreement*) (§ 960.3) are vague and overly broad, and, as such, allow for undue interpretation and discretion on the part of the regulator.
- There needs to be greater specificity and greater limits with respect to additional information that may be requested of an applicant in connection with the license application and review process (§ 960.6, Review procedures for license applications). This would improve transparency and predictability for industry.
- In § 960.6(d), NOAA should be required to provide specific reasons for denying an application request so that the applicant can assess whether it has a basis for appeal or revisions to accommodate specific issues. Providing only a “concise statement of the facts in the record determined to support the denial,” as currently provided for in the regulations, is vague and potentially insufficient.
- In order to help licensees demonstrate compliance through NOAA monitoring activities, NOAA should adhere to specific procedures regarding advance notification of visits. NOAA should explore whether certain elements of an audit or inspection could be satisfied by a written certification by the licensee with respect to that element (*e.g.*, pre-launch inspection of the spacecraft). Visiting remote ground stations on a less frequent basis, as opposed to every year, and using other means of disclosure and monitoring to assure enforcement of reasonable rules could create additional efficiencies.

4. What steps should NASA take to begin assessing the viability of public-private partnerships to support future earth observation systems and associated NASA data requirements?

A. The first steps would be to ask industry for ideas, conduct an analysis of alternatives for meeting mission requirements, and then have competition for a pilot program or demonstration effort. In deciding whether to “make” data with its own systems or to “buy” data from others, NASA needs to decide how to allocate risks between what it provides and what it expects others to provide, to assess the “regret costs” if a private provider fails to perform as expected, and what fallback options exist. Most critically, NASA needs to gain and retain in-house expertise to

ensure due diligence and oversight of public funds, whether used for traditional acquisitions, cooperative agreements, or commercial purchases.

For NASA, one of the more difficult tasks is likely to be getting an objective market analysis to assess economic viability and thus what risks the agency may be exposed to. It can be difficult to assess the size of addressable markets for new data products and judge the amount of capital required to successfully bring them to market. Yet doing so is a necessity for deciding whether commercial data buys are viable and sustainable. In this regard, there may be differences in assessing the viability of cooperative agreements to acquire "developmental" versus "operational" data. Data that have never before been acquired (*e.g.*, for decadal science priorities) may be worth doing as a cooperative agreement if the private party can do so more efficiently and at less cost than in a traditional government procurement. There may not be any demand other than NASA. In contrast, a cooperative agreement for operational data (*e.g.*, weather and ongoing climate measurements) may offer more efficient acquisitions as well as opportunities to offset some fixed costs with revenue from non-governmental demand.

The Earth Science Applications program may offer attractive opportunities for partnerships with non-NASA revenue due to its focus on practical applications of remote sensing data. A NASA partnership agreement could, for example, license data to other agencies such as the National Geospatial-Intelligence Agency (NGA), and the Departments of Interior, Agriculture and Commerce for their mission needs. NGA today supports other agencies, including NASA, by licensing data it acquires from commercial remote sensing suppliers to meet national security needs.

5. In the late 1990s, the National Aeronautics and Space Administration (NASA) carried out a \$50 million program to acquire Earth remote sensing data from commercial providers. An analysis in 2000 by Dr. Pace referred to this program as "an experimental success." An analysis in 2008 by Dr. Goward called the program "very successful." In contrast, the NASA Office of Inspector General concluded in 1999 that the program was "unable to fulfill its goal to reduce NASA's costs of remote sensing science and technology programs through competition within the commercial remote sensing industry" and that "additional congressionally directed data buy programs are not warranted." What lessons did NASA, Congress, and the commercial sector learn-or what lessons should they have learned-from the commercial data buy program?

A. It is my view that the program succeeded in demonstrating the technical and contractual feasibility of acquiring commercial remote sensing data for NASA needs. But NASA science requirements are very specialized and there was no commercial market to share fixed costs with or realistic competition given NASA was the sole market. Commercial data buys may not be the most cost-effective approach to meeting NASA needs in every case, but they should be part of the analysis of alternatives. Whether or not a particular commercial acquisition is cheaper than a government-only program will depend on agency requirements, the state of technology, the existence of non-government demand, and the willingness of the agency to acquire data licenses in a more "arms length" relationship.

A lesson learned should be for each side, industry and agency, to conduct their own make or buy

analysis, decide what level of risk each is willing to take, and what kind of contractual relationship makes sense for both parties. There is unlikely to be a “one size fits” all answer for meeting NASA Earth science data needs. The most promising cooperative agreements will be where there are customers other than NASA. If there are none, then a cooperative agreement is unlikely to be attractive, but a commercial data buy could still offer savings compared to a traditional space system acquisition.

a. If the NASA Earth Science program were to initiate another commercial data buy program, should it be conducted differently from the previous program? If so, how?

A. NASA should ask industry for ideas and how it might construct a new commercial data buy program and what uncertainties such a program might answer. It is not a question of whether private providers can provide high quality science data. Rather, can they satisfactorily do so more efficiently and at less cost and on a continuing basis, if needed, compared a traditional NASA space system acquisition?

NASA pilot programs might seek to broadly support multiple NASA Mission Directorates in addition to the Science Mission Directorate (SMD). SMD is an obvious customer, but its needs can be very specialized and non-NASA markets may be small or non-existent. In contrast, the Earth Science Applications program, with its relatively small budget and practical application focus, may find commercial data purchases more attractive. Aside for decadal science priorities, NASA has needs for “exquisite” operational data for climate monitoring that might be provided by private systems. NASA’s human spaceflight exploration effort needs data about the Moon, asteroids, and Mars that might be supplied by private systems (see for example, NASA’s Lunar CATALYST program).

NASA Earth Science Division researchers can already propose to purchase commercial data (paid for by the NASA grant or contract) when the purchased information is required by, or would substantially enhance, their research activity. Under circumstances where commercial data or products could serve multiple NASA-funded researchers/communities and an all-government license for same (purchased by another agency) does not already exist, program managers can direct that such procurements be initiated.

Since the last NASA commercial data buy experiment, the National Geospatial Intelligence Agency has become the major buyer of commercial remote sensing data for the U.S. Government. In some cases, all-government licenses already exist, especially for high-resolution imagery, through NGA purchases from systems such as NextView, EnhancedView, and ClearView. Foreign data from systems such as RADARSAT-2, TerraSAR-X/Tandem-X Digital Elevation Maps, COSMO-SkyMED from the Italian Space Agency, and ALOS-2 from the Japanese Space Agency are also available via NGA. As an alternative to a NASA-based data buy, consideration should be given to an interagency agreement with NGA for it to use its existing relationships and buying power to meet NASA needs. This may be faster and less expensive than creating a new NASA-specialized process.

Questions submitted by Rep. Jim Bridenstine, Chairman, Subcommittee on Environment

1. Last time you testified before this committee, we discussed potential commercial opportunities NOAA could utilize to satisfy its mission of accurate and timely weather forecasts to protect lives and property. Since then, NOAA released a draft commercial space policy. From your experience with the Department of Commerce and the National Space Policy, do you feel this draft policy can adequately facilitate commercial space-based approaches for NOAA's observation requirements?

A. The draft commercial space policy from NOAA is a good, partial step forward. It is appropriately anchored in the 2010 National Space Policy, which commits the United States to lead generally and with regard to U.S. space-related science, technology and industrial bases. However, the draft NOAA policy does not go far enough in encouraging the active participation of an emerging and dynamic U.S. commercial space industry. NOAA should be more transparent on the kinds of data that it needs or will need to satisfy environmental, scientific, or other requirements in order to seek new and credible ways to conduct its public missions.

NOAA should describe what kinds of data are needed (*e.g.*, in environmental and scientific requirements) and to allow the market to innovate and compete in response. NOAA would, of course, retain the right and responsibility to validate that commercial inputs are of the highest possible quality for public purpose. NOAA's view of the international obligation to share commercially acquired environmental data, and potential impact on the commercial weather market, is not convincing. It fails to account for an approach that defines core or essential data sets – which must be shared under NOAA's international obligations – and non-essential data sets that would remain within the full commercial rights of the vendor.

U.S. leadership in remote sensing (and, by extension here, other space mission areas) is at risk because of a failure to adapt to these new circumstances, including how they affect policy, regulation, and government interactions in the market. NOAA's draft Commercial Space Policy acknowledges the commercial industry's role, as well as the fact that its full, open, and free data policy has multiple benefits, including supporting the development of commercial weather services. However, NOAA's approach should move beyond the principle of embracing the commercial space industry to more specific and practical steps, including, for example, increased pilots and experimentation, collaborative methods for data evaluation and validation, and more clarity on the timelines, funding, and rules associated with private-public partnerships.

2. NASA has a number of missions that used to be the responsibility of NOAA. Were they still under the purview of NOAA, it is possible NOAA could seek commercial solutions to these missions under the recently released commercial space policy. However, NASA does not have a commercial space policy for its earth observation requirements. In your opinion, should they have a similar policy?

A. A specific policy for this specific sector does not seem necessary. NASA already conducts ambitious cooperative agreements such as the commercial cargo and commercial crew efforts. In addition, NASA is already incentivized to look for cheaper solutions to meet operational data needs due to the process of senior review to decide when to terminate missions that have met

their initial scientific objectives.

One could easily conceive of NASA-funded land imaging research and applications that utilize commercial products in fundamental ways. However, this is not always consistent with the objectives and directions from the Congress. In particular, in the FY15 appropriations bill, Senate language that was incorporated verbatim in the Conference report called for initiation of Landsat-9 as a lower-cost "copy" of Landsat-8, with the specific admonition: "The Committee [Conference] does not concur with various administration efforts to develop alternative 'out of the box' approaches to this data collection —whether they are dependent on commercial or international partners." Clearly, the intent of Congress is for NASA to develop a next-Landsat satellite, rather than examine the designs of innovative systems and the use of partnerships as recommended by the last Earth science decadal survey.

3. It is my understanding that many of NASA's 26 earth observation satellites are performing operational rather than experimental functions. However, the National Space Policy of 2010 requires the government to "transfer routine, operational space functions to the commercial space sector." Is NASA in compliance with this policy?

A. From my experience with NASA culture, I have no doubt that NASA would like to transfer routine, operational space functions to the private sector so they could focus on missions that have never been done before. The challenge often comes in whether NASA is allowed to stop doing what might be seen as operational missions. The deeper problem is that NASA has become a convenient place for civil observation satellites due to its technical expertise and limitations on NOAA's appropriation accounts.

If operational satellites were transferred to private ownership and operation, for greater efficiencies, the question of paying for them would still remain (along with which appropriations accounts to use). Such transfers may just be a privatization function, not really a transfer to a commercial space sector that meets private market demands. Depending on the price the government has to pay, privatization can be an effective means of saving money, but it should not be confused with commercialization.

Questions submitted by Rep. Donna Edwards, Ranking Member, Subcommittee on Space

1. Under what conditions, if any, are public-private partnerships a good idea for NASA to incorporate in their Earth science research and applications program? What are best practices from current and prior Earth science partnerships that should guide any future public-private partnerships that NASA considers?

A. Cooperative agreements are more likely to be successful if NASA is able to articulate stable, well-known requirements and identify significant sources of non-government demand. The agency and the private partner need to be in agreement on the appropriate allocation of risks, whether technical, cost, schedule, market, or financial, between them. All parties must allow for changes and continual communications as initial conditions change over long-term projects. NASA needs to avoid creating a monopoly situation for itself that places future taxpayers at risk. It also needs to ensure it retains sufficient internal intellectual capital to monitor and understand the performance of the private partner. This capacity is important not only for agency oversight, but also to ensure the government has fallback options to meeting its requirements in the event the private partner fails to perform.

Best practices for NASA would include retaining the ability to build and operate remote sensing instruments and spacecraft using civil servants and on-site contractors even while predominately relying on the private sector. It means conducting analysis of alternative studies, with input from industry and other agencies, to decide whether NASA should make or buy a particular Earth science capability. Once in operation, routine senior reviews should decide whether and when to transfer a government capability to the private sector for either privatization or commercialization. If the private sector is able to meet NASA needs with a privately developed capability which also attracts non-NASA demand, then that would likely be the most cost-effective approach to choose.

2. In your testimony, you said, "There should be procurement on-ramps to enable experimentation and large-scale innovation in parallel with current government systems and international partnerships." Could you elaborate on what a procurement on-ramp would be and how it would work in practice?

A. I would think of a procurement on-ramp like a funded Space Act agreement that would provide industry an opportunity to meet NASA data needs. These efforts would provide an essential "first buyer" for new capabilities and allow industry to demonstrate its ability to meet government needs. If industry were able to meet government demand at an attractive price, this would inform the analysis of alternatives on major acquisition decisions. Such on-ramps need not be limited to NASA, but could include interagency efforts with NGA as well.

The primary purpose of a procurement on-ramp effort is to reduce technical and market risks and provide alternatives to traditional government acquisition processes. The necessity of clear and stable requirements is more plausible for on-going, operational missions (e.g., Landsat) than for one-off, first time decadal science missions. If industry were able to show it is able to meet NASA needs and is able to raise private capital and find non-NASA customers, then NASA

would have the option of proceeding with a commercial data buy rather than a traditional spacecraft acquisition. If the private provider fails, the government would fall back to doing a traditional, more expensive procurement. An important consideration is that the pilot program be conducted well in advance of deciding to build a government-owned spacecraft. Thus, an on-ramp would be an experiment targeted to inform decisions in pre-Phase A and Phase A stages, and perhaps through Phase B, but not later.

3. If NASA determines that public-private partnerships will provide cost savings to the government while meeting Earth science research requirements, what in your view would be the best way to set them up? What contractual vehicles should NASA use? Would a new program need to be established or could these partnerships be formed under the aegis of existing Earth Science programs?

A. NASA Earth Science Division researchers can already propose to purchase commercial data (paid for by the NASA grant or contract) when the purchased information is required by, or would substantially enhance, their research activity. Under circumstances where commercial data or products could serve multiple NASA-funded researchers/communities and an all-government license for same (purchased by another agency) does not already exist, program managers can direct that such procurements be initiated.

Since the last NASA commercial data buy experiment, the National Geospatial Intelligence Agency (NGA) has become the major buyer of commercial remote sensing data for the U.S. government. In some cases, all-government licenses already exist, especially for high-resolution imagery, through NGA purchases from systems such as NextView, EnhancedView, and ClearView. Foreign data from systems such as RADARSAT-2, TerraSAR-X/Tandem-X Digital Elevation Maps, COSMO-SkyMED from the Italian Space Agency, and ALOS-2 from the Japanese Space Agency are also available via NGA. As an alternative to a NASA-based data buy, consideration should be given to an interagency agreement with NGA for it to use its existing relationships and buying power to meet NASA needs. This may be faster and less expensive than creating a new NASA-specialized process.

NASA already has existing authorities with its Space Act agreements and could consider Other Transactional Authorities (e.g., DARPA) if it felt it had a strong justification for doing so. NASA could use commercial data license for non-developmental items, either directly acquired or through others agencies such as NGA's government-wide licenses. NASA need not create a program separate from the Science Mission Directorate. Rather, use of commercial data licenses could be a routine trade-off analysis done as part of the agency's acquisition strategies.

4. Are there international implications of public-private relationships in remote sensing? If so, what are they and how should they be addressed?

A. The United States is committed to complying with the 1986 *United Nations Principles Relating to Remote Sensing of the Earth from Outer Space*, which includes making data of a "sensed state" available to that same state on reasonable terms and conditions. For NOAA in particular, there is also the *International Charter on Space and Major Disaster* that obligates parties to provide data in support of international disaster relief. The primary international

concern with public-private partnerships in remote sensing is the degree to which they undercut the free international exchange of scientific and meteorological data --- an important concern to NASA and NOAA. From a U.S. industry perspective, support from foreign governments for their own PPPs can be a source of competitive disadvantage. For example the Japanese government supports the ALOS-2 program as a public-private partnership and the satellite manufacture was reserved for Japanese industry. However, because ALOS-2 is not a government satellite, its data has not been freely shared in a manner consistent with the principles of Group on Earth Observations (GEO), to which Japan and the United States belong.

An approach to dealing with competing interests of industry and science would be to consider the source of development funds for civil Earth observation capabilities. If the development was government funded, then the Earth observation data ought to be in the public domain. If privately funded, then the data would be privately owned and data licensing would be a private decision. If there were a mixture of public and private funding in development, then intellectual property rights to data would be part of the negotiation for funding, as in many private investment situations. Governments could choose to put data in the public domain, or not, as part of their goals for participation in a PPP. Trade remedies for unfair government supports to industry could be part of existing bilateral and multilateral trade agreements as they are in other economic sectors.

A key point is that sufficient flexibility exists in the negotiation of data licenses and the structuring of public-private partnerships to enable international scientific cooperation without undercutting sales to non-government buyers. U.S. policy needs to balance the benefits of the open international exchange of scientific data for non-commercial purposes with incentives for private sector innovation and commercial growth.

5. While at RAND, you were part of a team that reported on public-private partnerships. Your team concluded: "The structure of the arrangements in themselves is not critical to success." Rather, what you cited as critical include such factors as having an active, informed user community and mechanisms for that community to signal its preferences to the "controlling" bodies. How might this happen in practice?

A. At the time of the RAND report, the geospatial community was not as developed and sophisticated as it is today. The increasing fusion of remote sensing data from aerial and satellite platforms, the ubiquitous use of GPS, and greater distributed computing power has resulted in multiple, active informed user communities. The ability of these communities to signal their preferences is much greater today due to increased buying power and wider understanding of the productivity benefits to be gained from geospatial data.

NASA licensed data could be made available for non-commercial use by universities to educate and train students for industry and government. This is widely done today for well-known systems such as MODIS and Landsat, but university access to the latest data from newer constellations such as Skybox, PlanetLabs, and BlackSky would ensure the user community remains up to date. Interactions between university users with established and newer companies can stimulate innovation and concepts for applications that may be offered back to NASA and NOAA.

6. The National Academies' 2002 report "Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research," summarized the challenges and issues associated with public-private partnerships that were ongoing at the time of the 2002 report. Among other things, the 2002 report said "Differences between the government and the private sector complicate negotiations on intellectual property and licensing agreements related to the use of privately owned remote sensing data, on data management and data continuity, on the development of measures of performance for public-private partnerships, and on realistic cost accounting in these partnerships". It has been thirteen years since that report was released. Are those issues still relevant? If so, are we any closer to a resolution of them?

A. Yes, the issues remain relevant as the differing interests of the respective scientific and business communities have not fundamentally changed. The issues are unlikely to be resolved as much as they will be managed and new precedents will be set. As mentioned earlier, my view is that if a government pays for development, data from that development should be freely available. If development is privately funded, the government should not compel data to be placed in the public domain. Even if government is paying for operations, private data rights creating economic advantage should be respected if the capability would not have existed without private investment.

It should be noted that NASA takes care in archiving and distributing all the commercial data it acquires while balancing differing policy objectives. NASA makes all of its non-commercial data freely and openly available through its data systems, in accordance with Group on Earth Observations (GEO) and U.S. open-data policies. When individual principle investigators purchase commercial data, they generally keep ownership and are governed by their purchase licenses regarding sub-distribution and other conditions. When NASA procures the commercial data, it attempts to negotiate the most open license possible, but they also must observed contractual restrictions when it hosts the data products on NASA data systems. This makes data management a complex but common challenge in the United States and worldwide.

7. Are the enacted policies and authorities that enabled the advent of commercial remote sensing adequate for supporting both the future needs of the Federal government and the growing commercial remote sensing industry? If not, what additional policies and authorities are needed and why?

A. The United States has been a leader in both technical and regulatory aspects of commercial remote sensing, but is facing increasing competition abroad and bureaucratic barriers at home. These challenges are the result of increasing technical change and globalization in which existing regulations and process are outdated and unresponsive. These conditions are deterring innovation and in some cases causing U.S. firms to consider moving their operations overseas.

Additional policies and authorities are not so much the issue as updating existing policies and regulations and most importantly, focusing on consistent execution and oversight. NOAA's current regulatory resources are inadequate to keep up with changes in remote sensing technology and constellation architectures. NOAA is trying to do too much with too little and it

needs to update and streamline its licensing process and well as add some additional resources.

NOAA and the Department of Commerce have authorities and processes to create relief from impractical regulatory enforcement actions, such as the need to physically visit ground stations each year. New licenses are taking too long to review and approve, creating delays and uncertainties for U.S. industry while foreign competitors seek to fill the vacuum. The most infamous case example of this was the loss of U.S. leadership in commercial space-based radar to Canada, Germany, and Italy. While one can argue that those countries provided industrial supports that the United States would not, it is also true that regulatory opposition and uncertainty bought crucial time for those competitors to come to market.

In general, despite supportive policy statements over multiple Administrations, the United States has not been leaning forward enough in the licensing of capabilities outside of familiar electro-optical imagery. Regulatory practice has not followed the policy statements. It would be helpful to make clearer that the burden of evidence for denying a U.S. license should be the demonstration of a clear potential harm to national security or public safety – in short, license applications should have a presumption of approval unless NOAA receives clear, documented evidence from its interagency reviews that harm would occur as result. In the licensing process, agencies should not be asked to judged the economic value or viability of a commercial capability or balance it against other interests. (As a separate matter, agencies may consider economic factors as part of decisions to participate in a cooperative agreement with private commercial remote sensing firms.)

a. Are there policies at NASA that encourage and facilitate public-private partnerships, and if not, should there be?

A. Yes, NASA has a fairly well developed set of policies for encouraging and facilitating cooperative agreements. At the same time, there are also strong pressures to stick with traditional acquisition systems due to perceptions that risks will outweigh potential cost savings. Continual efforts, such as the aforementioned pilot programs, procurement on-ramps, and interagency cooperation, are needed to reduce risks and reveal potential cost efficiencies from greater utilization of private sector capabilities.

Privatization, commercialization, and public-private partnerships are not “silver bullets” to solving agency budget pressures. Rather, they are tools that should be a routine part of agency acquisition strategies to get the most public benefit from the use of public resources.

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Hearing: "Exploring Commercial Opportunities to Maximize Earth Science Investments"
 Response of Dr. Walter Scott, Founder and Chief Technical Officer, DigitalGlobe

Submitted by	Question	Answer
<p>Rep. Brian Babin</p>	<p>Which aspects of NASA's Earth Science program are most suitable for commercial partnerships today? Which aspects do you expect to become suitable of the next 10-15 years?</p>	<p>Without having had recent conversations with NASA about their Earth Science program, it would be difficult to presume what would be most suitable for commercial partnerships today or in the future. That said, I think an increased dialogue with industry could help determine where NASA might be able to partner and what cost savings and benefits might be realized from such partnerships.</p>
<p>Rep. Brian Babin</p>	<p>DigitalGlobe has a longstanding relationship with the National Geospatial-Intelligence Agency (NGA). DigitalGlobe imagery acquired by NGA is also available to U.S. civilian agencies for science and humanitarian purposes. Can you please describe how DigitalGlobe imagery has been used by U.S. civil agencies? Can you please share how your data has been used by the science community more broadly? And to what extent do you think your company could meet NASA, NOAA, and other civil space agency earth observation requirements?</p>	<p>While we do currently support agencies outside of NGA, such as, SOCOM, DIA, DTRA, IARPA, FAMS and a few smaller projects at State and USAID, there are a wide range of other agencies who utilize geospatial information with whom we do not yet work, or work with at a meaningful scale.</p> <p>That said, however, we do currently operate the Global EGD (Enhanced GEOINT Delivery) system on behalf of NGA for making high resolution, orthorectified satellite imagery available to an estimated 100,000 government end users as quickly as 12 minutes after it has been acquired. Anyone with a .mil or .gov email address can have access to this platform, providing DigitalGlobe's daily take on an easy to use platform. This is paid for by NGA and is not an added expense to other government users.</p>

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Submitted by	Question	Answer
Rep. Brian Babin	The last time Congress updated the statute governing the regulation of private Earth remote sensing space systems was 1992. That's over 20 years. Do you have any opinion as to whether the legislation needs to be updated?	This legislation does need to be updated. The world is a much different place than it was 20 years ago. Technology is moving at a pace like never before. This begs for reform that will encourage innovation and allow U.S. companies to stay ahead of their international competitors (vs achieving parity), instead of burdening them with outdated, unnecessary administration. Unfortunately, we often experience challenges within the current regulatory environment. For example, we waited 14 months for approval of a resolution issue that should have been resolved within 120 days.
Rep. Brian Babin	What challenges, if any, do you experience in the regulatory environment and do you have any recommendations on how to improve it?	There currently is no forcing function that holds the U.S. government to that timeline. This has a great impact to investment timelines and future decisions for a commercial company. The regulations are simply outdated and have not kept up with the pace of technology and innovation.

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Rep. Brian Babin	As your industry competes against foreign companies, are there ways for the U.S. government to work with industry to make sure our companies remain world-wide leaders?	Regulatory overreach and regulations that are improperly applied are having great impacts to industry—it stifles progress and creates an uneven playing field for U.S. commercial companies competing with foreign subsidized competitors. A consistent approach to both regulation and licensing can send an important signal to commercial entities that you welcome their involvement are committed to being a strong partner over the life of the contract. The U.S. government must tailor policy and regulations to reflect the fact that remote sensing is no longer a U.S. only, exclusively government based effort.

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Submitted by	Question	Answer
Rep. Jim Bridenstine	<p>In your testimony, you say that the satellite imaging industry represents "an ideal model for public-private partnerships." Are there any ways that the current public-private partnership between DigitalGlobe and the federal government could be strengthened or improved moving forward that we need to ensure are incorporated as we look to expand opportunities for commercialization of NASA's earth science requirements?</p>	<p>I believe there are three areas:</p> <ol style="list-style-type: none"> 1. Modernization of the regulatory framework 2. Predictability. The fact that EnhancedView runs through 2020 has enabled us to make the investments needed to serve NGA. While there is every indication that the demand for our services remains exceedingly strong post 2020, the more we can be assured of demand post 2020, the more we will be able to invest in ensuring that we have capabilities in place to meet that demand. 3. Leverage our strengths. Both we and the U.S. Government have invested substantially in enabling the widespread use of commercial imagery throughout NGA and its downstream consumers. We've created infrastructure that enables imagery to be in the hands of an end user a dozen minutes after collection. We're pioneering a new generation of geospatial analytic tools that convert imagery into analyzable information at country or continent scale. We see the leadership of NGA being very forward leading in terms of adopting this commercial innovation, and would look to other agencies doing the same.

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<p>Rep. Jim Bridenstine</p>	<p>Has DigitalGlobe had any discussions with NASA about providing imagery and geospatial data?</p>	<p>We have not had any recent discussion with NASA on providing imagery or geospatial data.</p>
<p>Rep. Donna Edwards</p>	<p>Under what conditions, if any, are public-private partnerships a good idea for NASA to incorporate in their Earth science research and applications program? What are best practices from current and prior Earth science partnerships that should guide any future public-private partnership that NASA considers?</p>	<p>I can't speak directly to NASA's program requirements, or how public-private partnerships may meet them, but I can say that I believe NGA and the USG have benefited immensely from the public-private partnerships, such as the EnhancedView contract with DigitalGlobe. As I outlined in more detail in my written testimony, I believe the keys to a successful public-private partnership are:</p> <ol style="list-style-type: none"> 1. Balancing the needs of the U.S. government with your commercial partner 2. Promoting a predictable regulatory regime designed to enable innovation <p>Promoting transparency and stability in budgetary processes.</p>
<p>Rep. Donna Edwards</p>	<p>If NASA determines that public-private partnerships will provide cost savings to the government while meeting Earth science research requirements, what in your view would be the best way to set them up? What contractual vehicles should NASA use? Would a new program need to be established or could these partnerships be formed under the aegis of existing Earth Science programs?</p>	<p>I have not had recent conversations with NASA on their specific Earth science research requirements, so I am unfamiliar with possible contractual vehicles and would not have the background to suggest how those various partnerships should be set up specifically.</p>

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Submitted by:	Question	Answer
Rep. Donna Edwards	How important has the U.S. Government's financial and technical investment in Earth observation technology and research been to the establishment of a vibrant commercial Earth observation industry? How do you see such investments benefiting industry in the future? How much of DigitalGlobe's total market do sales to the U.S. Government comprise?	<p>U.S. government financial and technical investment in earth observation technology has been very important in that it has funded the industrial base that our industry leverages for components and systems.</p> <p>While government investment has been beneficial to industry, industry has also been beneficial to the government. As a commercial company in a highly competitive industry, we must constantly innovate to meet the needs of our customers, which operate on much faster product cycles than the government. This has had a reciprocal benefit for the U.S. government, our largest customer, as it leverages investments we make to serve our commercial customer base, driving greater efficiencies in the products and services we deliver.</p>
		Currently, U.S. government contracts comprise about 50% of DigitalGlobe's business.

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Submitted by:	Question	Answer
Rep. Donna Edwards	What restrictions, from an intellectual property standpoint, might companies impose on data products resulting from public-private partnerships? How would companies address the need for researchers to understand the specifications of instruments in order to ensure the accuracy of their research?	Much like computer software companies, we make our money by building or collecting once, then selling (or, more accurately, licensing) that imagery multiple times to different customers. As such, if a customer is allowed to widely or freely disseminate our products, then their commercial value is diminished or outright destroyed. There is potentially a model in which we could make all of a certain type of imagery publicly available, as Landsat data is today, but its cost would be great as to offset the opportunity cost of not being able to sell it to other customers. The government would need to make the tradeoff between completely open availability at a higher cost versus, for example, a lower cost for open availability for research but not for open dissemination.
		As to your question on the need for researchers to understand the specification of instruments, DigitalGlobe regularly shares our specs and actual performance with those who use our data. Most commonly, researchers need to know how well our data is calibrated. We are prepared to share our results and accuracies. However, there is a tendency for researchers to want to hold design reviews or get in manufacturing and test details that are often proprietary to either DigitalGlobe or our vendors. Such information

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<p>Rep. Donna Edwards</p>	<p>Recognizing the difference between the operational role of NGA and the scientific research role of NASA, what are some of the lessons learned from the NGA-DigitalGlobe partnership, and would they be applicable to potential partnerships with NASA? After participating in a partnership with NGA for over a decade, what would you say were the biggest successes? What are the biggest difficulties?</p>	<p>may be ITAR controlled, may not be shareable based on vendor constraints, or needs to be managed by Non-Disclosure Agreements."</p>
	<p>As I have detailed in my written testimony, innovative public-private partnerships, like EnhancedView, can and do provide specific, considerable advantages to the U.S. government:</p> <ul style="list-style-type: none"> • Cost Savings • Mutual interest in delivering performance and value • Innovation • Sharability <p>While there are many significant advantages to public-private partnerships, there have also been some tough lessons learned in the past decade. We would stress a few important considerations in order to ensure that any program is successful.</p> <ul style="list-style-type: none"> • Balance the needs of the U.S. government with your commercial partner. • Promote a predictable regulatory regime designed to enable innovation • Promote transparency and stability in budgetary process. 	

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Submitted by:	Question	Answer
Rep. Donna Edwards	Are the enacted policies and authorities that enabled the advent of commercial remote sensing adequate for supporting both the future needs of the Federal government and the growing commercial remote sensing industry? If not, what additional policies and authorities are needed and why?	The enacted policies and authorities are well over 20 years old. The world looks immensely different than it did 20 years ago. Technology is moving at pace like never before. It's time to update these policies to reflect innovation and US leadership.

Responses by Mr. Robbie Schingler

Questions from Chairman Babin:

Q1: What public-private partnerships in the field of Earth observations don't currently exist, but should? In other words, are there any NASA or NOAA programs that could and should be made public-private partnerships?

A1: As I noted in my written testimony and real-time Q&A, the concept of public-private partnerships should expand and include new programs given the maturity of the American commercial aerospace sector. The U.S. government has relied on the aerospace industry as contractors where the U.S. government drives the requirements and the process for space missions. NASA and NOAA should consider procurements that **buy the outcome, not the process** (aka Data Buys); give market signals and become a **solid second customer** (let industry find market traction and have the U.S. government become an enterprise customer); utilize Other Transaction Authorities (OTAs) to partner with industry to infuse capital to augment and/or accelerate technology development of capability that allows for the government to become a future enterprise customer. Your questions are directed toward NASA and NOAA, and my comments address your questions, however it is applicable to some, but not all, other U.S. Government space activities.

Data Buys. Data Buys can be information feeds that are commercially available, however it should be noted that many new entrants don't have an enterprise-level, operational capability as yet. Instead, they do have technology demonstrations and NASA and NOAA could enter into an "Early Access Data Buy" to evaluate the utility of commercial data for government missions and needs. In some cases, such data may not have been available before and its applications may be novel and new. Therefore, with such new and novel data sets or applications there should be more than a "simple" data-buy; there should be an in-depth engagement to understand the true capability emerging in industry in terms of more affordable satellites, distributed or disaggregated systems, new sensors, affordable launch, and automation. These all need to be more fully understood, and then industry should use what is learned to help inform strategies and procurement. In another case, the data or service may be in an early/alpha phase that allows for the government to give useful feedback to the commercial enterprise to iterate and improve its capability.

Novel Capabilities. NASA and NOAA could explore the concept of satellites-as-a-service in support of instrument development, test, and demonstration programs where access to space may otherwise be unavailable or expensive. I would further encourage the Committee's support of both the Venture Class launch program, and more venture-class Earth science missions (highlighted in the 2007 Earth science decadal survey), which I noted in my testimony before the committee. In particular, Venture class missions and Space Technology projects may provide an excellent opportunity to fully explore the possibilities of public-private-partnerships beyond data buys. As I noted in my testimony before the Committee, when thinking about this mission class NASA can now think about a portfolio of different Earth science activities, some of which bring about a rapid amount of capability, some which take more risk, and all of which could likely be at decreased cost as compared to previous efforts. A portfolio of government-supported projects will lead to more robust government programs, have the potential to affect future critical path plans, and stimulate creative entrepreneurs to enter into the market.

Q2: A 2002 study by the National Academies made a number of recommendations for public private partnerships and other commercial involvement in Earth science. These recommendations included open scientific distribution and reuse of data, public data archiving, agreed data standards, well defined performance measures, and realistic cost accounting. To what extent have NASA and the private sector made progress on addressing these issues?

a. What do you see as the most challenging barriers to successful commercial involvement in Earth science?

A2: As noted in my written testimony, I believe NASA, NOAA, and USGS have made great progress toward enabling commercial capabilities by making data available. Much of this is pioneered by NASA to make its federally funded science data as ‘public domain.’ NASA, and therefore the U.S. Government, leads in this across all other international government agencies. Since this data is in the public domain, many commercial organizations, such as Google, Microsoft and Planet Labs, benefit from publicly available Landsat 8 data, Moderate Resolution Imaging Spectroradiometer (MODIS) data, Shuttle Radar Topography Mission (SRTM) data, and cloud data made available by the NOAA NOMADS system. Further, Amazon, Planet Labs, and others have been working closely with USGS to make Landsat data available to all via Amazon Web Services, and we make Landsat 8 data available via our own Application Programming Interface (API) as well. NASA’s policy to maintain a curated “golden copy” of NASA generated data via its Distributed Active Archive System (DAACs) works very well and allows for commercial players to feed this data into systems that allows for higher-level analysis. NOAA is currently working on more detailed policies and procedures for how commercially available weather data can meet standards for weather prediction.

As to challenges, I believe one important challenge is the need for that in-depth engagement between industry and the government that I refer to above. When the government has the opportunity to more fully understand the true capability emerging in industry, and then can more thoughtfully and creatively consider ways to integrate those emerging capabilities into their architectures and strategic, there will be an obvious opportunity for a new relationship between industry and government. Another challenge is NASA’s use of other transactional authorities, which I mentioned in both my written testimony and my testimony before the Committee. As I said before the committee, NASA should “buy the outcome, not the process,” so that they can be consumers in an open marketplace. To do so, the agency should look into the use of vehicles beyond those that are standard cost-plus, or even fixed-price FAR contracts. I encourage the Congress to consider giving NASA and NOAA more flexibility to explore the use of its other transactional authorities.

Q3: Which aspects of NASA’s Earth Science program are most suitable for commercial partnerships today? Which aspects do you expect to become suitable over the next 10-15 years?

A3: I have already referenced the opportunity for data-buys and satellites-as-a-service, which I see as two immediate opportunities, and would again note the need for an in-depth government-industry engagement. I would also highlight again the opportunity presented to the community by Venture class Earth science missions, the Space Technology Program for high-risk, high-

return items, and OTAs for rapid and novel industry-government partnership. Over the medium-to-long term, these approaches may become the best opportunity for public-private partnerships, and if done collaboratively could potentially free-up resources for NASA's focus on Tier 1 decadal science missions.

Missions that have a commercial utility and require an on-going monitoring capability, like remote sensing (visible, infra-red, RADAR, etc.), space weather, space traffic management and terrestrial weather activities, can be the basis of new commercial enterprises in space. I would strongly encourage NASA and NOAA to engage with these novel companies to ensure they know the U.S. government needs, engage in early data buys for assessment and feedback, and when commercially proven, become a solid second customer.

Q4: In your testimony you spoke about the principles of good partnership between the private sector and government to meet science requirements. How would you recommend NASA put these principles into practice? And what next steps would you recommend NASA take to assess commercial and other private-public partnership opportunities?

A4: Aside from the traditional contractor relationship between NASA and industry, there are three categories where the U.S. government should encourage deeper engagement with the private sector along the lines of the principles I listed in my written testimony: Launch, Development, and Data Subscriptions.

Launch. This is a systemic challenge for the U.S. aerospace sector, and something that each stakeholder within the U.S. government needs to identify. If launch was more easily, cheaply, and quickly available, there will be a new era in commercial, military and scientific aerospace sector. NASA has already supported where they can with enabling secondary payloads for universities and non-profit organizations (via the NASA NanoSat Launch initiative), utilization of the ISS as a launch platform, and the newly created Venture Class Launch Services Contract. But, NASA can and should do more. The NASA NanoSat Launch initiative should open up to commercial players, the Venture Class Launch Services Contract should be expanded with more resources, and NASA should engage with the Department of Defense on an integrated U.S. Government strategy to bring a vibrant national launch capability back to the United States. While launch is out of scope for your question, it is a perennial inhibitor for a vibrant aerospace sector, including new, novel science activities.

Development. My testimony highlighted principles and an evolution in an industry-government relationship, and includes exploring satellites as a service, joint R&D initiatives leveraging OTAs, and engagement in early data buys for scientific and mission utility assessments.

Data Subscriptions. When commercial industry has proven the technical, operational and commercial readiness for data feeds derived from operational spacecraft, the U.S. government, having been involved in the early data assessments, should engage as an enterprise customer where they are one of many commercial consumers of an operational product. Such an architecture will allow for an industry to evolve, attract additional competition, and continue having commercial businesses invest in new technologies and capabilities that support their customers, including the U.S. government.

In a general sense, I would recall my written testimony and note that the commercial cargo program for the International Space Station (ISS) has been an excellent method of supporting industry in ways that were not immediately part of the ISS human spaceflight mission. NASA should consider how all of its programs in space science, Earth science, and human spaceflight could continue to find similar opportunities.

Questions submitted by Ranking Member Edwards:

Q1: Under what conditions, if any, are public-private partnerships a good idea for NASA to incorporate in their Earth science research and applications program? What are best practices from current and prior Earth science partnerships that should guide any future public-private partnerships that NASA considers?

I believe we are coming into an era in our national space activities where public-private partnerships, which as noted in my testimony, means something more than the standard government-to-industry prime contractor relationship. The U.S. government has relied on the aerospace industry as contractors where the U.S. government drives the requirements and the process for space missions. With the emergence of new commercial aerospace actors, and advancement of technology and manufacturing capabilities, the cost of building new aerospace systems are decreasing. NASA, NOAA and the rest of the U.S. Government should encourage these trends to continue and create an attractive framework for the emergence of what could be, the **next, new industry**. There are three categories where the U.S. government should encourage deeper engagement with the private sector along the lines of the principles I listed in my written testimony: Launch, Development, and Data Subscriptions. The second and third categories have specific opportunities for NASA Earth Science.

Development. My testimony highlighted principles and an evolution in an industry-government relationship, and includes exploring satellites-as-a-service, joint R&D initiatives leveraging OTAs, and engagement in early data buys for scientific and mission utility assessments. These activities encourage an in-depth engagement to understand the true capability emerging in industry in terms of more affordable satellites, distributed or disaggregated systems, new sensors, affordable launch, and automation. These all need to be more fully understood, and then industry should use what is learned to help inform strategies and procurement. I think past successes point to the need for this kind of in-depth knowledge and discussion, and there need to be more in the future.

Data Subscriptions. When commercial industry has proven the technical, operational and commercial readiness for data feeds derived from operational spacecraft, the U.S. government, having been involved in the early data assessments, should engage as an enterprise customer where they are one of many commercial consumers of an operational product. Such an architecture will allow for an industry to evolve, attract additional competition, and continue having commercial businesses invest in new technologies and capabilities that support their customers, including the U.S. government.

It will take some time for commercial industry to develop the operational, technical and business capabilities to allow for Data Subscriptions to fulfill core NASA needs. Until then, a traditional procurement approach could be employed to fulfill things like NOAA's overall weather satellite mission, or the Tier 1 missions identified in the National Academies' 2007 Earth Science Decadal Survey. To generalize, one can say that an exception to pursuing a public-private partnership should happen when the data needed is identified to be of the highest priority to the government's mission that it must be procured, managed, and owned by the government; or, when it is clear that there is no interest from any non-government entity to pursue the capability.

As I think we are seeing, there are fewer instances where the latter is the case in the realms of monitoring remote sensing and weather missions.

I recognize that this suggests an entirely new paradigm for NASA activities, and perhaps such an approach needs to evolve over time. But there are successful examples, to answer your question -- Dr. Busalacchi discussed SeaWiFS with the committee, and I believe Dr. Pace discussed data buy programs from the 1990s. I would highlight my written testimony to the Committee about the success and benefits from the commercial cargo program for access to the International Space Station (ISS) as well. These all are examples of government taking a little bit of risk, industry partners making their own investments, and both industry and government taking time to fully understand the capabilities of the other.

Q2: If NASA determines that public-private partnerships will provide cost savings to the government while meeting Earth science requirements, what in your view would be the best way to set them up? What contractual vehicles would NASA use? Would a new program need to be established or could these partnerships be formed under the aegis of existing Earth Science programs?

In a general sense, much of this was discussed before the committee, in that the how they are “set up” may be matter of how NASA and private companies can establish a commercial agreement with the right licensing terms – terms that can effectively balance government needs and company needs so that both parties get the full benefit of the partnership. As noted by several of the witnesses before the committee, license agreements might differ based on data type, value of the data to a particular company’s market strategy, etc. NASA and NOAA may need to establish a core set of *principles* that are “must haves” – but that can be achieved through a variety of licensing models or terms.

In my testimony before the committee I highlighted the opportunity that is being presented to our community by the combination of NASA’s support to venture class launch capabilities, and the call for more venture-class Earth science missions from the 2007 Earth Science Decadal survey. I noted further that NASA can now think about a portfolio of different Earth science activities, some of which bring about a rapid amount of capability, some which take more risk, and all of which could likely be at decreased cost as compared to previous efforts. In this context I would again emphasize my answers about the need for an in-depth dialogue between NASA and industry on capabilities and strategy.

Lastly, I would recall points from both my written testimony and my testimony before the Committee about NASA’s use of other transactional authorities. As I said before the committee, NASA should “buy the outcome, not the process,” so that they can be consumers in an open marketplace. To do so, the agency should look into the use of vehicles beyond those that are standard cost-plus, or even fixed-price FAR contracts. I encourage the Congress to consider giving NASA and NOAA more flexibility to explore the use of its other transactional authorities.

Q3: How important has the U.S. Government’s financial and technical investment in Earth observation technology and research been to the establishment of a vibrant commercial Earth observation industry? How do you see such investments benefiting industry in the

future? To what extent does your business model depend on the U.S. Government being a major customer?

A3: It cannot be overstated how critical the U.S. Government's investments have been to this industry. The U.S. Government invented the practice of observing the Earth from space; it created the science out of whole cloth, invented new sensor and instrument technologies for observation from space, trained or funded the training of generations of professionals to build models, create tradecraft, and establish world-leading state of the art practices in this field. At Planet Labs we consider ourselves to be in partnership with the civil government Earth observation community every day. This based on the unparalleled foundation of openly available data NASA and NOAA collect. We use Landsat-8 data for a variety of purposes, Moderate Resolution Imaging Spectroradiometer (MODIS) data, archived data from the Shuttle Radar Topography Mission (SRTM), the National Elevation Dataset, and cloud data from the NOAA NOMADS system. In sum, NASA and NOAA provide a critical foundation for our activities, and without their publicly available data we would be significantly challenged to accomplish our goals.

Regarding Planet Labs' business model, we are not dependent on the U.S. government as a customer, and we have always believed that our smartest approach the U.S. government as a customer is to seek them as a **solid, second customer**. More generically, an entrepreneurial company should be in the commercial market and see the technology trends, the market adoption, and the pricing and positioning to build a true commercial product. This market is larger, moves faster, and demands operational excellence, cost effectiveness and adoption and a continuous adoption of new technologies. Once there is a product to market fit, then the commercial company should pursue the U.S. government as an enterprise customer. The U.S. government should feel more secure because the business isn't reliant on the government contract to survive, and there is competition in the market for continuous cost/performance increases. In that regard, the government can be a consumer, and offer feedback to companies like Planet, and others, in the same way other customers do, and can benefit from the collective, community drive to improve product quality and customer service. I highlight the benefits to this approach for both Planet Labs, and the government, in my written testimony. In short, I believe there are opportunities to feed back into NASA and NOAA and help them further improve their own work, in way akin to how they already help us.

Q4: What restrictions, from an intellectual property standpoint, might companies impose on data products resulting from public-private partnerships? How would companies address the need for researchers to understand the specifications of instruments in order to ensure the accuracy of their research?

A4: In general, Planet Labs wants to find a way to work with the U.S. government, and be accommodating to its needs, as to do so would, in my opinion, be to the long-term benefit of both Planet Labs and the U.S. government. As I noted above, I spell out some of the mutual benefits of working together in my written testimony, and the benefit to the U.S. government from working with industry as the space renaissance beings to flourish was discussed at length during the hearing.

In the framework articulated above in Answer #1, I could foresee a Development project where all the data becomes public domain, but the company keeps the intellectual property of the hardware and software created. In the Data Subscription model, this could take many forms where the data can have U.S. Government - specific licenses, or the commercial entity can choose to license a degraded version of its product under public domain. These are examples.

Planet Labs has a deep-seated appreciation for some of the unique needs of the government as a customer - both from the time that my co-Founders and I spent at NASA and from our company's commitment to openness, sharing, and collective participation in making our Planet better for ourselves and future generations. To that end, we are developing what we call an Ambassador's program, wherein academics and researchers can have access to our data for the purpose of conducting research and analysis and contributing to publications in the scientific literature. Our commitment to open data is truly demonstrated via our Open California initiative. Through a beta release of our web platform, our Open California release includes two years of archival imagery of the whole state of California from our RapidEye satellites, the most recent 2 months of data from our Dove satellites, and new data collected from both constellations on an ongoing basis, with a two-week delay. The data will be available under an open license, specifically Creative Commons, Attribution-ShareAlike 4.0 International. The spirit of this license is to encourage R&D and experimentation, whereby data users must in turn open their work, just as we are opening ours. It will enable the community to discuss their experiments and applications openly, and thus, we hope, establish the early foundation of a new geospatial ecosystem.

The decision to open a portion of our data was a deliberate one, made after significant consideration as to how to balance between our commercial needs, our commitment to our existing customers, and our values to bring data to the people who need it. We want to work with the U.S. government in a similarly deliberative and balanced fashion. We strongly believe, however, that these discussions should happen in the context of the detailed, evaluative engagements between agencies and industry as described above, wherein both parties are examining the utility of a particular data set to a given need or needs and the benefit of different approaches to either sharing or not sharing data.

Q5: Are the enacted policies and authorities that enabled the advent of commercial remote sensing adequate for supporting both the future needs of the Federal government and the growing commercial remote sensing industry? If not, what additional policies and authorities are needed and why?

A5: In the broadest sense, much of the policy language impacting commercial remote sensing activities may initially appear to be "right" at a high level. Agencies are directed to use commercial capabilities to the maximum practical extent and should do so when it is clear that it will create cost-savings to the government. But as I believe I have outlined above, the nature of the government-industry relationship is ready to change, and this can sometimes be hard to reflect in high-level policy language as it is typically written.

The challenge, then, is in truly recognizing that the opportunities for benefits and cost-savings will become more evident and available if one engages with industry and begins crafting programs to take advantage of them. To a degree, this is a mindset about policy implementation

Responses by Dr. Samuel Goward

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND
TECHNOLOGY SUBCOMMITTEE ON SPACE
SUBCOMMITTEE ON ENVIRONMENT**

"Exploring Commercial Opportunities to Maximize Earth Science
Investments"

Dr. Samuel Goward, Emeritus Professor of Geography, University of Maryland at College Park

Questions submitted by Rep. Brian Babin, Chairman, Subcommittee on Space

1. The cost of Landsat-8 ran about \$1 Billion. The Administration is now preparing to develop Landsat-9 follow-on, essentially a clone of Landsat-8. Given the rapid development of technology and innovation in the private sector, does it make sense for NASA to do this and what would you recommend NASA do?

Landsat 8 was launched in February 2013 with a design life of 5 years. Additional fuel was added to the satellite to extend the mission. The current proposal is to develop Landsat 9, as a clone of Landsat 8, for launch in ~2023 or perhaps 2021. This is relatively risky since after 2018, Landsat 8 will be beyond its design life, in particular the thermal infrared sensor. This also insures that Landsat mission will be a single satellite observatory once Landsat 7 terminates (it has currently been in orbit for sixteen years) for the foreseeable future.

Assuming that there are cost savings associated with building a Landsat 8 clone, these savings should be used to build and launch a smallsat Landsat 8 equivalent as soon as possible. It should be possible to do so in 3 years following authorization. This would not only maintain the two satellite configuration, currently supported by Landsats 7 and 8 but also test and demonstrate the validity of using contemporary smallsat technologies to achieve future Landsat science and applications goals. The bases for doing so have recently been reviewed and reported under the NASA/USGS Sustainable Land Imaging Program by the Architecture Study Team (AST)

2. What is the most important single way the Landsat Program could be improved?

From its origins the Landsat concept has always been viewed as multiple, on-orbit satellite mission which would relatively high temporal repeat frequency, cloud-free observations. For cloud-prone land areas this most likely will require near-daily orbital repeat frequency. Accomplishing this goal will require a combination of international and, potentially, public-private partnerships. This will also require substantial cost reductions in mission development and operations costs. With contemporary satellite and computer technologies this is well within our grasp.

3. Is it possible to develop a public-private partnership to explore current and emerging technologies that would advance the Landsat mission while reducing costs?

Depends upon how a public-private partnership is defined. For example the government could assist one or more entrepreneurs to develop advanced, low cost satellite systems to achieve the goal stated above. If successful these private partners might well be able to assist the government in maintaining a satellite constellation that would achieve the desired daily orbital repeat frequency. Such observations might have considerable value, potentially commercial, in managing natural resources such as agriculture, grasslands and forestry.

4. What are the fundamental technical requirements for the Landsat Mission and could they be met through a public-private partnership?

The fundamental technical requirements of the Landsat Mission are well expressed in the technical requirements for the Landsat 8 mission. These requirements have evolved from the earliest multispectral imaging studies carried out at USDA labs, Purdue and Michigan Universities in the 1950s. More recent advances has been accrued from experience gained from the MODIS sensor, where it became clear that avoidance or adjustment for atmospheric contamination including haze, water vapor and clouds contributed substantially to the quality and reliability of the land surface measurements. Today the hardest requirement to meet is moderate resolution thermal infrared observations in two or more spectral bands. Contemporary approaches in this area so great promise but may need more government investment before they can become commercially successful.

One requirement that is not currently defined is the temporal resolution of the observations. The early experimental systems called for at least satellites at any given time., with the potential for more for an operational system. This was reaffirmed when the experimental Landsats 4 and 5 were developed. More recent experience with AVHRR and MODIS show that near daily repeat coverage is needed to achieve weekly cloud-free observations for the more cloud-prone and therefore biologically active land areas of the planets

5. It is well known that spaceflight mission costs are heavily driven by total mass (weight), volume (size) and power requirements. Are there viable "smallsat" alternatives for collecting Landsat-quality observations?

Certainly the MVP mission requirements drive some mission costs. However, one of the primary advantages of smallsats is that multiple satellites can be orbited on the same launch vehicle thus substantially reducing launch costs. There are numerous examples of smallsat technologies that are in orbit today which are accomplishing defined mission goals. Nothing quite so complex as the Landsat mission has yet to be achieved but the design and configuration of such a mission exists today. The current lacking ingredient is the will and commitment to move in this direction.

6. Given the much smaller size of smallsat solutions, can they be taken seriously? Will they last as long as past Landsat missions?

In at least one well-known case, Surry Satellite Technology (SST) has many long-lasting examples in orbit. They had an early issue with batteries which appears now to have been resolved. Several of their satellites that have lasted over a decade. Again, a fully Landsat-like equivalent has yet to be flown but the design has been developed under funding from NASA/USGS Sustainable Land Imaging Program Architecture Study Team, There are, no doubt, many other examples, many flown for DOD.

7. An important value of the Landsat satellite series is the long record of continuous and comparable observations that has allowed users to document changes to the land surface and other features over decades. What are the advantages and disadvantages of deploying Landsat instruments on other polar-orbiting satellites, government and commercial, instead of recreating the same Landsat satellite as the one vehicle for the U.S. moderate resolution land imaging mission?

One of the advantages of a smallsat sensor design is that it could piggybacked on launches that had greater capacity than the sensor requires. However, when placing two or more sensors on satellite platform many problems can arise. When OSTP directed that the Landsat sensor be flown on the DOD-NOAA NPOESS satellite, there were so many interactions between the Landsat sensor and other sensors on that satellite that it was not technically feasible nor cost-effective to take this approach. The tension is always in the details.

- a. What would be the tradeoffs, if any, between preserving aspects of data continuity by launching a single satellite, versus guarding against gaps in data continuity, should there be a satellite or instrument failure, by collecting moderate resolution data from a more dispersed array of satellites?

As noted above, the answer to this question is in the details of any specific proposed approach. Under the right circumstances, such a multi-platform approach should work.

- 8. One model for public-private partnerships is the "anchor tenant" model, in which the government commits to being a major customer of a commercial enterprise. The SeaWiFS instrument for satellite measurements of ocean color was an example of this approach. The private sector incurred the costs of instrument and satellite development, placement in orbit, and data acquisition; NASA committed \$43.5 million over five years to purchase scientific data, while a commercial company (now merged with Dr. Scott's company, DigitalGlobe) retained rights to the data for operational and commercial purposes. What lessons did NASA, Congress, and the commercial sector learn-or what lessons should they have learned-from the SeaWiFS experience?

Dr. Busalacchi provided a more complete answer to this question with respect to SeaWiFS. The "anchor-tenant" or "data buy" concept was a first focus of the Landsat 8 procurement. The only viable bid was rejected by NASA HQ because the company bid was viewed as providing no cost savings to NASA. This suggests that the company did not believe that there would be any additional market for the observations beyond what would be provided to NASA. A similar situation appears to be developing in the NGA procurement of high spatial resolution multispectral images (see recent Space News articles).

- a. If the NASA Earth Science program were to initiate another anchor tenant partnership with the private sector, should it be conducted differently from the SeaWiFS partnership? If so, how?

Do not know enough of the details of the SeaWiFS partnership to comment.

- 9. In the next ten years, what major developments do you believe will be made in commercial remote sensing, and could these developments be used by NASA to improve their imaging efforts or decrease the cost of remote sensing to the government

The commercial remote sensing companies are moving quickly into value-added products that take advantage of parallel computing and Cloud data storage. As these companies shift away from strictly image procurement toward information provision, the value and cost of images used in this process should come down substantially since they will no longer be the sole product of the industry.

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"Exploring Commercial Opportunities to Maximize Earth Science Investments"

Dr. Samuel Goward, Emeritus Professor of Geography, University of Maryland at College Park

Questions submitted by Rep. Donna Edwards, Ranking Member, Subcommittee on Space

1. *Under what conditions, if any, are public-private partnerships a good idea for NASA to incorporate in their Earth science research and applications program? What are best practices from current and prior Earth science partnerships that should guide any future public-private partnerships that NASA considers?*

In those cases where the goals of both partners are in agreement, then there may be an opportunity for a public private partnership. For example, when Resource21 originally bid on Landsat 8, their vision was to employ a sensor with a 10m spatial resolution, which would serve as their commercial product. They would then aggregate the data to a 30m spatial resolution for NASA earth science use. If the company has been able to maintain a viable bid, this concept might well have worked out to everyone's benefit. Unfortunately this did not successfully move forward. Sounds as if the SeaWiFs program had a similar financial problems but over a longer time period.

One of the great difficulties in US government-industry partnerships are the cultural/professional differences found between these two entities. The adversarial relation that developed over government procurements, particularly during and after World War II, have left little room for productive collaboration between these organizations. It is unlikely that in the absence of significant cultural changes that such partnerships will succeed (more later)

2. *If NASA determines that public-private partnerships will provide cost savings to the government while meeting Earth science research requirements, what in your view would be the best way to set them up? What contractual vehicles would NASA use? Would a new program need to be established or could these partnerships be formed under the aegis of existing Earth Science programs?*

My experience with the NASA Science Data Buy Program was that members of the NASA Earth science community needed to feel engaged with and benefiting from such public-private partnership programs. If such an approach is "imposed" on the community they will go elsewhere (look at the history of early Landsat commercialization and the science community turning to NOAA weather satellite data to continue their research). Scientists have neither the resources nor the patience to get caught between US government and US private industry. The rules of engagement must be clear and feasible.

As noted above the adversarial relation between government and industry needs to be damped down, giving more room for collaboration and cooperation to achieve US goals such as improving the US economy and advancing US technological prowess. Mistrust between partners is most likely to lead to failure as has happened in the limited effort to partner in land imaging. We must simply find a better way to collaborate that through our current or improved procurement system

3. *What, if any, intellectual property issues regarding commercial Earth observing systems would need to be addressed in potential public-private partnerships used to support fundamental scientific research, and how might such issues be addressed?*

Intellectual property issues arose in the Landsat EOSAT era because they were combined with excessive data costs (\$4000-\$6000 per scene) and severe data exchange restrictions. This forces most University and government land researchers to abandoned Landsat as a source of observations.

To be fair to industry, at this time there were serious concerns that University researchers, particularly in the applied sciences, would unfairly compete with the value-added private companies. This problem did not occur, probably because of the pricing and laws imposed. However it also brought to a halt all further progress in the use of Landsat observations to scientifically study the Earth' land areas, at least with Landsat. If it were clear that data costs would be minimal or nonexistent for government/university researchers but that such researchers could not compete in the value-added market place, then such problems would also not occur but would also sustain land scientific research.

However one issue that is often overlooked in this discussion is that there is a transition period between when researchers have developed new products that may have applied value and when the private sector is interested in marketing such products. During this time if aggressive government action is taken to prevent researchers working on applications studies, with or without industry partners, to avoid unwanted low cost completion this could easily damage emerging commercial products, as well as disenfranchise the individuals and intuitions that originated the concepts, thus stifling further advances from these innovators. Perhaps patent law needs to play a role here to protect all those involved.

4. *Does the U.S. government make the commercial remote sensing data that it purchases available to researchers? If so how, and to what extent are the data being used?*

Today a variety of commercial imagery from Geoeye and DigitalGlobe are made available to government funded researchers. This is done so through NGA, the USGS EROS center and University centers such as the Global Land Cover Facility at the University of Maryland. These data are extensively used as validation information for regional and global studies conducted with Landsat, AVHRR, MODIS and VIIRS.

5. *The National Academies' report "Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research", summarized the challenges and issues associated with public-private partnerships that were ongoing at the time of the 2002 report. Among other things, the 2002 report said that "Differences between the government and the private sector complicate negotiations on intellectual property and licensing agreements related to the use of privately owned remote sensing data, on data management and data continuity, on the development of measures of performance for public-private partnerships, and on realistic cost accounting in these partnerships". It has been thirteen years since that report was released. Are those issues still relevant? If so, are we any closer to a resolution of them?*

See the answer to 3 above. Seems as though everyone has calmed down somewhat from the hostilities that occurred during and shortly after the Landsat EOSAT commercialization debacle. Private industry has learned that scientists using their data may be the best way to evaluate and refine data quality (beta checking) and scientists have learned that private industry engineers and scientists are

made of the same cloth as their University/Government colleagues. Takes time to get used to working together.

The adversarial relation noted previously has a particularly perverse manifestation in this process, government and university researchers are generally encouraged to employ as many resources as possible to grow the STEM workforce and develop their institution homes. Industry on the other hand is primarily motivated by maximizing profits and therefore minimize expenses. It would be interesting to see if there is some way to blend the industry minimum expense approach with the research community maximize the STEM workforce goal. Now that would be a cultural paradigm shift!

6. *Are the enacted policies and authorities that enabled the advent of commercial remote sensing adequate for supporting both the future needs of the Federal government and the growing commercial remote sensing industry? Are there policies at NASA that encourage and facilitate public-private partnerships, and if not, should there be? If not, what additional policies and authorities are needed and why?*

Other than what I have said previously not sure I have enough legal authority to comment on this question. Seems like the bigger issues are in accessing the data a low or no cost while maintaining an appreciation that industry needed to make a profit in order to remain viable. This is certainly done in other sectors of our economy but as technology changes (e.g. the music industry) the business model needs to change as well. Tough but not an impossible problem to solve.

Responses by Dr. Antonio Busalacchi

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"Exploring Commercial Opportunities to Maximize Earth Science Investments"

Dr. Anthony Busalacchi, Professor and Director of the Earth System Science Interdisciplinary Center, University of Maryland

Questions submitted by Rep. Brian Babin, Chairman, Subcommittee on Space

1. One model for public-private partnerships is the "anchor tenant" model, in which the government commits to being a major customer of a commercial enterprise. The SeaWiFS instrument for satellite measurements of ocean color was an example of this approach. The private sector incurred the costs of instrument and satellite development, placement in orbit, and data acquisition; NASA committed \$43.5 million over five years to purchase scientific data, while a commercial company (now merged with Dr. Scott's company, DigitalGlobe) retained rights to the data for operational and commercial purposes. What lessons did NASA, Congress, and the commercial sector learn-or what lessons should they have learned-from the SeaWiFS experience?

SeaWiFS 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. 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.

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

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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 and its successor, VIIRS, which is currently manifested on Suomi National Polar-orbiting Partnership, or Suomi NPP. VIIRS is also a key instrument on NOAA's JPSS 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.

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.

In NRC, 2011, 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

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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".

Moreover, based on the SeaWiFs experience, the following are characteristics of a successful partnership between NASA and the private sector:

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

- *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.

- *Technical readiness as a measure of what observation methodology may be ripe for a public*

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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 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.*

- a. *If the NASA Earth Science program were to initiate another anchor tenant partnership with the private sector, should it be conducted differently from the SeaWiFS partnership? If so, how?*

For the most part from the NASA perspective, the same data buy approach could be used again because it resulted in considerable savings to the government/tax payer while providing high quality data. The fact that there has not been a SeaWiFS followon would suggest that the commercial market for the data was not as vast as estimated by OSC. An important lesson learned here is the need to critically examine the claims made by the private sector regarding the true resale market for such data.

2. *In the next ten years, what major developments do you believe will be made in commercial remote sensing, and could these developments be used by NASA to improve their imaging efforts or decrease the cost of remote sensing to the government?*

As stated above, 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 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,

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calibration, validation, and science data processing and reprocessing.

However, providing satellite image snapshots to real estate companies, mining concerns, urban planners, etc is a far cry from the long-term, stable, calibrated, and continuous data required by the Earth System Science Community.

Beyond the applications of satellite imagery, other areas that may be ripe for commercial development are radio occultation measurements of atmospheric temperature and humidity measurements, as well as mature sensing technologies that could fit in a cubesat or smallsat format.

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Questions submitted by Rep. Donna Edwards, Ranking Member, Subcommittee on Space

1. Are public-private partnerships a good idea for NASA to incorporate in their Earth science research and applications program? What is the best way to set them up? What contractual vehicles would NASA use? Would a new program need to be established or could these partnerships be formed under the aegis of existing Earth science programs?

In principle, public-private partnerships can be a good idea for NASA to incorporate in their Earth science research and applications program. However, it is not a panacea. The fact that there has not been a SeaWiFS followon would suggest that the commercial market for the data was not as vast as estimated by OSC. An important lesson learned here is the need to critically examine the claims made by the private sector regarding the true resale market for such data. 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.

2. What, if any, intellectual property issues regarding commercial Earth observing systems would need to be addressed in potential public-private partnerships used to support fundamental scientific research, and how might such issues be addressed?

In the case of SeaWiFS, 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.

*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 NRC study *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

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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."

3. Does the U.S. government make the commercial remote sensing data that it purchases available to researchers? If so how, and to what extent are the data being used?

The U.S. government makes very large purchases of data for national security purposes via the National Geospatial-Intelligence Agency (NGA). In the case of the Medea program that was run out of the CIA, previously classified environmental data as shared with a select group of cleared researchers.

If this question is restricted to commercial remote sensing data for civilian use, we are back to the subjects touched upon in my testimony. With respect to Landsat, since 2008 when the program began to provide all archived scenes at not charge to all users there has been explosive growth in use (cf., a 2014 paper in Nature here: <http://landsat.gsfc.nasa.gov/?p=9188>).

4. The National Academies' report "Toward New Partnerships in Remote Sensing: Government, the Private Sector, and Earth Science Research", summarized the challenges and issues associated with public-private partnerships that were ongoing at the time of the 2002 report. Among other things, the 2002 report said that "*Differences between the government and the private sector complicate negotiations on intellectual property and licensing agreements related to the use of privately owned remote sensing data, on data management and data continuity, on the development of measures of performance for public-private partnerships, and on realistic cost accounting in these partnerships*". It has been thirteen years since that report was released. Are those issues still relevant? If so, are we any closer to a resolution of them?

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The Academy has not done any reports since Towards New Partnerships, these issues are still relevant and, if anything, may be complicated further by the proliferation of commercial providers.

5. Are the enacted policies and authorities that enabled the advent of commercial remote sensing adequate for supporting both the future needs of the Federal government and the growing commercial remote sensing industry? Are there policies at NASA that encourage and facilitate public-private partnerships, and if not, should there be?

NASA has recently implemented an "Early Adopters" program for new missions such as soil moisture (SMAP) and ice sheet altimetry (ICESAT-II) to accelerate the development of applications from these missions. Applications are defined as innovative uses and integration of future data in decision-making activities and operational activities for societal benefit. This may include, but is not limited to, the use of future data in modeling, forecasting and/or operational activities. Applied research will provide fundamental knowledge of how such data products would be scaled and integrated into users' policy, business and management activities to improve decision-making efforts. Early Adopters are a subset of users who have a direct or clearly defined use for future data. While the Early Adopters program is rather new, most of the applications being considered are those for use by other Federal agencies or regional governmental use. Relatively, few examples exist within the Early Adopters program specific to or supportive of the commercial remote sensing industry.