

**Statement of
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National Research Council
The National Academies
Before the
Subcommittee on Space and Aeronautics
Committee on Science and Technology
U.S. House of Representatives**

June 28, 2007

Mr. Chairman, Ranking Minority Member Calvert, and members of the subcommittee: thank you for inviting me to testify on this important subject. My name is Richard Anthes, and I am the President of the University Corporation for Atmospheric Research (UCAR), a consortium of 70 research universities that manages the National Center for Atmospheric Research, on behalf of the National Science Foundation, and additional scientific education, training and support programs. I am also the current President of the American Meteorological Society. I appear today in my capacity as co-chair of the National Research Council (NRC)'s Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future.

The National Research Council is the unit of the National Academies that is responsible for organizing independent advisory studies for the federal government on science and technology. In response to requests from NASA, NOAA, and the USGS, the NRC has recently completed a "decadal survey" of Earth science and applications from space. ("Decadal surveys" are the 10-year prioritized roadmaps that the NRC has done for 40 years for the astronomers; this is the first time it is being done for Earth science and applications from space.) Among the key tasks in the charge to the decadal survey committee were to:

- Develop a consensus of the top-level scientific questions that should provide the focus for Earth and environmental observations in the period 2005-2020; and
- Develop a prioritized list of recommended space programs, missions, and supporting activities to address these questions.

The NRC survey committee has prepared an extensive report in response to this charge. Over 100 leaders in the Earth science community participated on the survey steering committee or its seven study panels. It is noteworthy that this was the first Earth science decadal survey, and the committee and panel members did an excellent job in fulfilling the charge and establishing a consensus – a task many previously considered impossible. A pre-publication version of the report was published in January 2007 and is available at www.nap.edu/catalog/11820.html ; the final version will be published later this year.

The committee's vision is encapsulated in the following declaration, first stated in the committee's interim report, published in 2005:

Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability.

As detailed in the committee's final report, and as we were forcefully reminded by the latest set of reports from the International Panel on Climate Change (IPCC), the world faces significant and profound environmental challenges: shortages of clean and accessible freshwater, degradation of terrestrial and aquatic ecosystems, increases in soil erosion, changes in the chemistry of the atmosphere, declines in fisheries, and above all the rapid pace of substantial changes in climate. These changes are not isolated; they interact with each other and with natural variability in complex ways that cascade through the environment across local, regional, and global scales. Addressing these societal challenges requires that we confront key scientific questions related to ice sheets and sea level change, large-scale and persistent shifts in precipitation and water availability, transcontinental air pollution, shifts in ecosystem structure and function, impacts of climate change on human health, and occurrence of extreme events, such as hurricanes, floods and droughts, heat waves, earthquakes, and volcanic eruptions.

As a result, one way or the other, our international neighbors and we will undoubtedly be taking steps in an effort to deal with the climate changes we will confront. And as we do so, policy makers and others will want to know if such steps are actually making a difference in addressing climate change. Yet at a time when the need for that kind of information has never been greater, we are faced with an Earth observation program that will dramatically diminish in capability over the next 10-15 years.

Between 2006 and the end of the decade, the number of operating missions will decrease dramatically and the number of operating sensors and instruments on NASA spacecraft, most of which are well past their nominal lifetimes, will decrease by some 35 percent, with a 50 percent reduction by 2015 (Fig. 1). Substantial loss of capability is likely over the next several years due to a combination of decreased budgets and aging satellites already well past their design lifetimes.

In its report, the committee sets forth a series of near-term and longer-term recommendations in order to address these troubling trends. It is important to note that this report does not "shoot for the moon," and indeed the committee exercised considerable restraint in its recommendations, which were carefully considered within the context of challenging budget situations. Yet, while societal applications have grown ever-more dependent upon our Earth observing fleet, the NASA Earth science budget has declined some 30 percent in constant-year dollars since 2000 (Fig. 2). This disparity between growing societal needs and diminished resources must be corrected. This leads to the report's overarching recommendation:

The U.S. government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications.

The report outlines near-term actions meant to stem the tide of capability deterioration and continue critical data records, as well as forward-looking recommendations to establish a balanced Earth observation program designed to directly address the most urgent societal challenges facing our nation and the world (see Fig. 3 for an example of how nine of our recommended missions support in a synergistic way one of the societal benefit areas—extreme event warnings). It is important to recognize that these two sets of recommendations are not an “either/or” set of priorities. Both near-term actions and longer-term commitments are required to stem the tide of capability deterioration, continue critical climate data records, and establish a balanced Earth observation program designed to directly address the most urgent societal challenges facing our nation and the world. It is important to “right the ship” for Earth science, and we simply cannot let the current challenges we face with NPOESS and other troubled programs stop progress on all other fronts. Implementation of the “stop-gap” recommendations concerning NPOESS, NPP, and GOES-R is important—and the recommendations for establishing a healthy program going forward are equally as important. Satisfying near-term recommendations without placing due emphasis on the forward-looking program is to ignore the largest fraction of work that has gone into this report. Moreover, such a strategy would result in a further loss of U.S. scientific and technical capacity, which could decrease the competitiveness of the United States internationally for years to come.

Key elements of the recommended program include:

1. Restoration of certain measurement capabilities to the NPP, NPOESS, and GOES-R spacecraft in order to ensure continuity of critical data sets.
2. Completion of the existing planned program that was used as a baseline assumption for this survey. This includes (but is not limited to) launch of GPM in or before 2012, securing a replacement to Landsat 7 data before 2012.
3. A prioritized set of 17 missions to be carried out by NOAA and NASA over the next decade (see Tables 1 and 2 below). This set of missions provides a sound foundation for Earth science and its associated societal benefits well beyond 2020. *The committee believes strongly that these missions form a minimal, yet robust, observational component of an Earth information system that is capable of addressing a broad range of societal needs.*
4. A technology development program at NASA with funding comparable to and in addition to its basic technology program to make sure the necessary technologies are ready when needed to support mission starts over the coming decade.
5. A new “Venture” class of low-cost research and application missions that can establish entirely new research avenues or demonstrate key application-oriented measurements, helping with the development of innovative ideas and technologies. Priority would be given to cost-effective, innovative missions rather than ones with excessive scientific and technological requirements.
6. A robust NASA Research and Analysis program, which is necessary to maximize scientific return on NASA investments in Earth science. Because the R&A programs are carried out largely through the Nation’s research universities, such programs are also of great importance in supporting and training the next generation of Earth science researchers.

7. Suborbital and land-based measurements and socio-demographic studies in order to supplement and complement satellite data.
8. A comprehensive information system to meet the challenge of production, distribution, and stewardship of observational data and climate records. To ensure the recommended observations will benefit society, the mission program must be accompanied by efforts to translate raw observational data into useful information through modeling, data assimilation, and research and analysis.

Further, the committee is particularly concerned with the lack of clear agency responsibility for sustained research programs and the transitioning of proof-of-concept measurements into sustained measurement systems. To address societal and research needs, both the quality and the continuity of the measurement record must be assured through the transition of short-term, exploratory capabilities, into sustained observing systems. The elimination of the requirements for climate research-related measurements on NPOESS is the most recent example of the failure to sustain critical measurements. Therefore, our committee recommends that the Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations. This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, and NPOESS programs.

In your invitation, Mr. Chairman, you asked me to explicitly address a number of issues and I am pleased to do so:

1. What, in your perspective, should be the top three priorities for the NASA Earth sciences program over the next five years, and what, if any, are the most significant challenges in meeting those priorities?

This is a somewhat difficult question to answer. Five years from now is well into the period covered by the Decadal Survey, and the Survey has recommended a balanced set of 15 high priority missions for NASA. This set of 15 missions was derived from over 100 proposed missions, so a great deal of priority setting has already taken place by the community. It is therefore important to make progress on all of these missions during the next five years, with greater attention paid to the recommended missions early in the queue (the 2010 to 2013 timeframe as described in the report). Thus my answer to this question will focus on the highest priorities to begin in FY08 in order to lay the foundation for implementing the full set of recommendations during the next decade.

- First, NASA should commit to and begin to implement its recommended Decadal Missions. Although, the NASA budget for Earth Sciences is not now adequate to implement the survey recommendations (see next question), a useful start can be made with modest resources. The survey's initial seven missions (2010-2013) should begin in 2008; the first four (CLARREO, SMAP, ICESat-II, and DESDynI) should begin intensive Phase A activities and the next three (for the time period 2013-2016 -- HypIRI, ASCENDS, and SWOT) should begin pre-Phase A studies. Increment needed beyond President's Request in FY08: \$90 million.

- Second, NASA should increase its suborbital capabilities. NASA's airborne programs have suffered substantial diminution and should be restored. In addition, NASA should lead in exploiting unmanned aerial vehicles (UAV/ technology). Both conventional and UAV aircraft are needed for instrument development, and hence risk reduction and technology advancement, and for their direct contribution to Earth observations. Increment needed beyond President's Request in FY08: \$10 million.
- And third, NASA should increase support of its Research and Analysis (R&A) program and in Earth System modeling. Improved information about potential future changes in climate, weather, and other environmental conditions is essential for the benefit and protection of society. This improvement will come from: a) better observations (the recommended missions and enhanced suborbital capabilities); b) more capable models of the Earth System; and c) a vigorous research program to use the observations in models and interpret the results. The R&A program has suffered significant cuts in recent years and these should be reversed. R&A investments are among the most cost-effective as they directly exploit on-going missions, advance knowledge to better define what is needed in the future, and sustain and develop the requisite scientific and engineering workforce. Increment needed beyond President's Request in FY08: \$20 million.

2. What are your perspectives on how well the FY 2008 budget request and out year projections for NASA's Earth science program align with the recommendations of the Earth science decadal survey?

The FY2008 budget request for NASA's Earth science program is inadequate to meet the recommendations of the decadal survey. Figure 2 compares the request and the requirements to carry out the recommendations. Even with an encouraging increase in the NASA Earth Science request for FY08, it still falls short of what is needed to get a full start on the recommended program. Moreover, the out year projections show a steady decrease when the requirements call for an increase to a level of about \$2.1 billion by 2010 with a level budget (in real dollars) after that.

This Committee's leadership on Earth sciences and the recent actions in the House appropriations process with respect to FY08 are encouraging and greatly appreciated. I am hopeful that the Congress and the Administration will ultimately support the actions taken by this Committee and the appropriators in the FY08 appropriations process and continue to build on that momentum into the future.

3. Could you please describe your views on how NASA might begin to implement the recommendations of the National Academies' Earth science decadal survey?

It is a truism that to begin a long journey you have to take the first step. NASA should first commit to implementing the recommendations in a timely fashion, and then begin developing implementation plans and schedules for the recommended missions and supporting research and technology development. I am encouraged that NASA is planning workshops to further analyze

the decadal survey recommended missions, but to develop the survey ideas further will require substantial investments.

Implementing the survey results will require modest increments in the NASA Earth Science budget, restoring the budget back to where it was in real dollars in the early part of this decade. This will require NASA to request the necessary resources and for Congress to provide them. Alternatively, Congress could take the lead and require NASA to implement the survey while providing the resources.

My recommended first specific steps for implementation are given in my answer to the first question.

4. What are your perspectives, as an individual researcher, on international collaborations in the Earth sciences, and what value would international collaborations offer in advancing the recommended missions in the decadal survey?

As the survey states, international partnerships can be very important in implementing complex expensive space missions such as recommended in the survey. Collaborations with other nations not only save scarce resources for all the partners, they promote scientific collaboration and sharing of ideas among talented people of all nations. Most of the smart people in the world do not live in the United States! International collaborations increase the brain pool to carry out the challenging proposed missions and use the observations in creative, innovative ways for the benefit of society.

However, international collaborations come at a cost. Any time partners are involved, control must be shared and the success of the mission depends critically on the performance of all the partners. If one partner runs into difficulties (e.g. financial support is withdrawn), the entire mission can be threatened. A successful collaboration also requires assurance that data will be shared and that U.S. scientists are full partners on teams that ensure adequate pre-launch instrument characterization and post-launch instrument calibration and validation. Other issues such as regulations governing the sharing of technologies (e.g. International Traffic in Arms Regulation--ITAR), governance and even language and cultural differences can make international partnerships more difficult and risky than “going it alone.” Nevertheless, the potential benefits outweigh the downsides and NASA, NOAA and their U.S. partners in academia and industry should seek opportunities for international partnerships at every turn.

Mr. Chairman, the observing system we envision will help establish a firm and sustainable foundation for Earth science and associated societal benefits through the year 2020 and beyond. It can be achieved through effective management of technology advances and international partnerships, and broad use of satellite science data by the research and decision-making communities. Our report recommends a path forward that restores U.S. leadership in Earth science and applications and averts the potential collapse of the system of environmental satellites. As documented in our report, this can be accomplished in a fiscally responsible manner, and I urge the committee to see that it is accomplished.

I close my testimony with a quote from Vice Admiral Richard H. Truly, former NASA Administrator, Shuttle Astronaut and the first commander of the Naval Space Command in a recent report *National Security and the Threat of Climate Change*. Admiral Truly speaks as one of 11 retired senior military officers who wrote this report that describes the serious threat of climate change to the nation's security. Describing his experience in space 25 years ago, Admiral Truly said:

I have images burned in my mind that will never go away---images of the earth and its fragility. I was a test pilot. I was an aviator. I was not an environmentalist. But I do love the natural environment, and seeing the earth from space was the experience that I return to when I think about what we know now about climate...

When you look at the earth's horizon, you see an incredibly beautiful, but very thin line. That thin line is our atmosphere. And the real fragility of our atmosphere is that there's so little of it...

The stresses that climate change will put on our national security will be different than any we've dealt with in the past. For one thing, unlike the challenges we are used to dealing with, these will come upon us extremely slowly, but come they will, and they will be grinding and inexorable...

Admiral Truly said he was not convinced of the importance of climate change by any person or interest group—he was convinced by the data. We as a nation must continue to provide the data on the Earth, for only the data can reveal the truth that will affect us all.

Thank you for the opportunity to appear before you today. I am prepared to answer any questions that you may have.

Supporting Tables and Graphics

**Earth Observing Instruments
(2000-2020)**

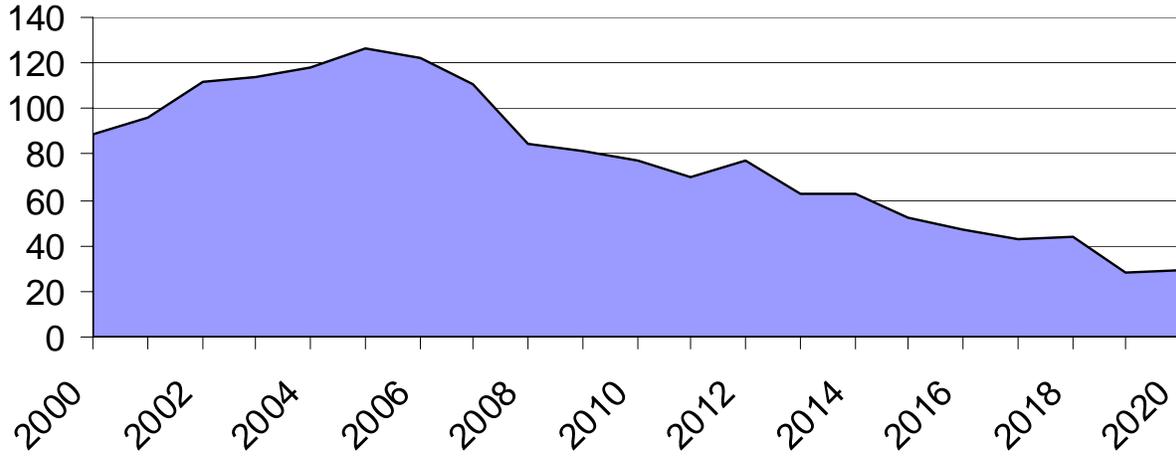


Fig. 1. Number of current and planned U.S. space-based Earth Observations instruments, not counting the recommended missions in the Committee’s report. For the period from 2007 to 2010, missions were generally assumed to operate for four years past their nominal lifetimes. SOURCE: Information from NASA and NOAA websites for mission durations.

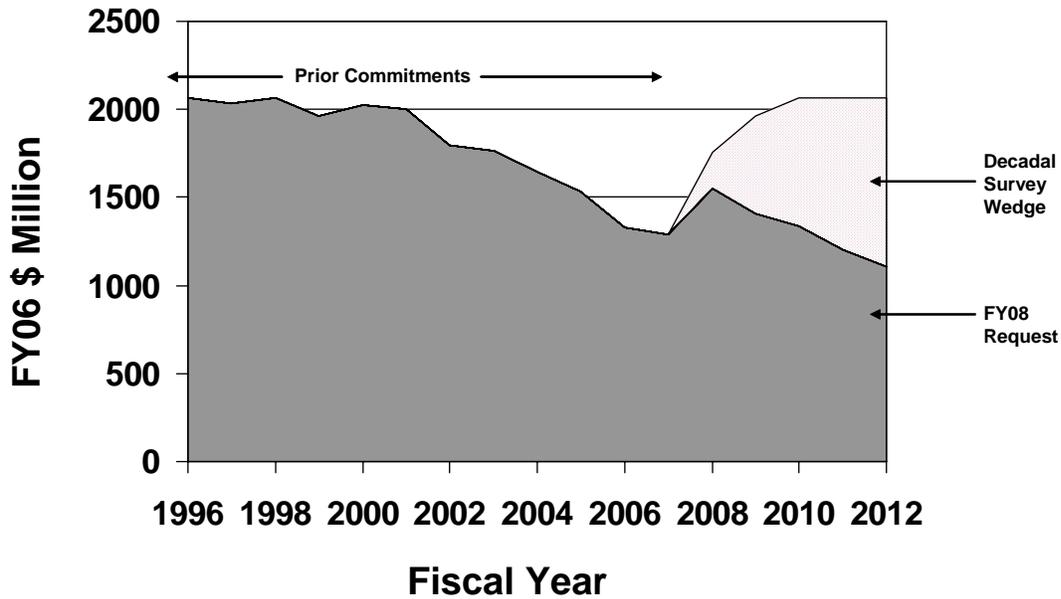


Fig. 2. NASA budget for Earth Sciences adjusted to constant FY 2006 dollars and adjusted for the effects of full-cost accounting. The required budget to implement the recommendations in the Decadal Survey Report would restore the Earth Sciences budget to the level at the early part of decade. SOURCE: President’s Budget Request for 2008 and Decadal Survey Report.

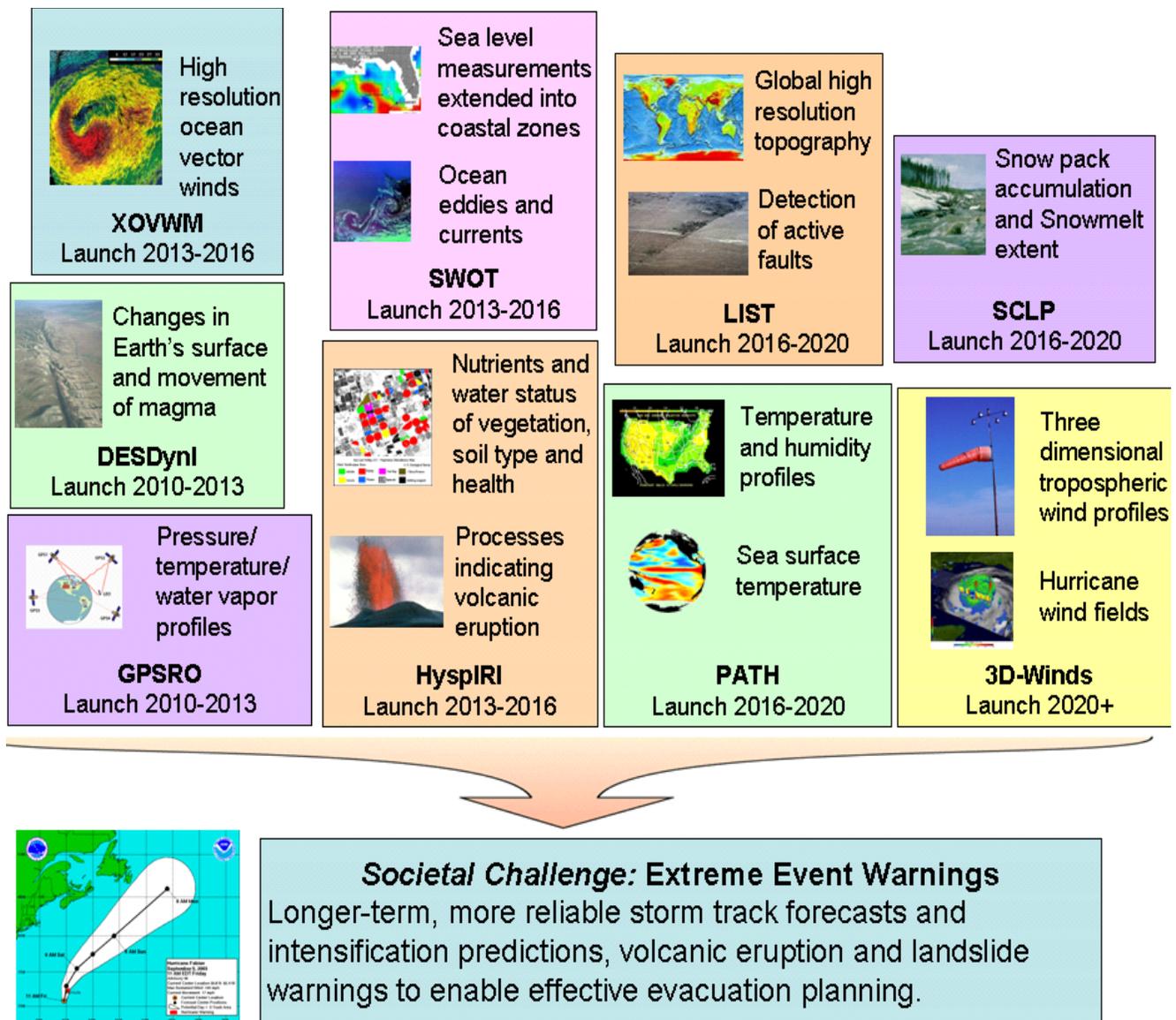


Fig. 3. Illustration showing how recommended missions work together to address societal challenges. Numerous additional examples are available in Chapter 2 of the final report.

TABLE 1. Launch, orbit, and instrument specifications for the recommended NOAA missions. Shade colors denote mission cost categories as estimated by the NRC committee. Green and blue shadings represent medium (\$300 million to \$600 million) and small (<\$300 million) missions, respectively. Detailed descriptions of the missions are given in Part II of the final report, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 - 2013—Missions listed by cost				
CLARREO (Instrument Re-flight Components)	Solar and Earth radiation characteristics for understanding climate forcing	LEO, SSO	Broadband radiometers	\$65 M
GPSRO	High accuracy, all-weather temperature, water vapor, and electron density profiles for weather, climate and space weather	LEO	GPS receiver	\$150 M
Timeframe 2013 – 2016				
XOVWM	Sea surface wind vectors for weather and ocean ecosystems	LEO, SSO	Backscatter radar	\$350 M

TABLE 2. Launch, orbit, and instrument specifications for the recommended NASA missions. Shade colors denote mission cost categories as estimated by the NRC ESAS committee. Pink, green, and blue shadings represent large (\$600 million to \$900), medium (\$300 million to \$600 million), and small (<\$300 million) missions, respectively. Missions are listed in order of ascending cost within each launch timeframe. Detailed descriptions of the missions are given in Part II of the final report, and Part III provides the foundation for selection.

Decadal Survey Mission	Mission Description	Orbit	Instruments	Rough Cost Estimate
Timeframe 2010 – 2013, Missions listed by cost				
CLARREO (NASA portion)	Solar and Earth radiation, spectrally resolved forcing and response of the climate system	LEO, Precessing	Absolute, spectrally-resolved interferometer	\$200 M
SMAP	Soil moisture and freeze/thaw for weather and water cycle processes	LEO, SSO	L-band radar L-band radiometer	\$300 M
ICESat-II	Ice sheet height changes for climate change diagnosis	LEO, Non-SSO	Laser altimeter	\$300 M
DESDynI	Surface and ice sheet deformation for understanding natural hazards and climate; vegetation structure for ecosystem health	LEO, SSO	L-band InSAR Laser altimeter	\$700 M
Timeframe: 2013 – 2016, Missions listed by cost				
HyspIRI	Land surface composition for agriculture and mineral characterization; vegetation types for ecosystem health	LEO, SSO	Hyperspectral spectrometer	\$300 M
ASCENDS	Day/night, all-latitude, all-season CO ₂ column integrals for climate emissions	LEO, SSO	Multifrequency laser	\$400 M
SWOT	Ocean, lake, and river water levels for ocean and inland water dynamics	LEO, SSO	Ka-band wide swath radar C-band radar	\$450 M
GEO-CAPE	Atmospheric gas columns for air quality forecasts; ocean color for coastal ecosystem health and climate emissions	GEO	High and low spatial resolution hyperspectral imagers	\$550 M

ACE	Aerosol and cloud profiles for climate and water cycle; ocean color for open ocean biogeochemistry	LEO, SSO	Backscatter lidar Multiangle polarimeter Doppler radar	\$800 M
Timeframe: 2016 -2020, Missions listed by cost				
LIST	Land surface topography for landslide hazards and water runoff	LEO, SSO	Laser altimeter	\$300 M
PATH	High frequency, all-weather temperature and humidity soundings for weather forecasting and SST ^a	GEO	MW array spectrometer	\$450 M
GRACE-II	High temporal resolution gravity fields for tracking large-scale water movement	LEO, SSO	Microwave or laser ranging system	\$450 M
SCLP	Snow accumulation for fresh water availability	LEO, SSO	Ku and X-band radars K and Ka-band radiometers	\$500 M
GACM	Ozone and related gases for intercontinental air quality and stratospheric ozone layer prediction	LEO, SSO	UV spectrometer IR spectrometer Microwave limb sounder	\$600 M
3D-Winds (Demo)	Tropospheric winds for weather forecasting and pollution transport	LEO, SSO	Doppler lidar	\$650 M

^a Cloud-independent, high temporal resolution, lower accuracy SST to complement, not replace, global operational high accuracy SST measurement.