Free Executive Summary

Ensuring the Climate Record from the NPOESS and GOES-R Spacecraft: Elements of a Strategy to Recover Measurement Capabilities Lost in Program Restructuring

Committee on a Strategy to Mitigate the Impact of Sensor Descopes and Demanifests on the NPOESS and GOES-R Spacecraft, National Research Council

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Summary

The nation's next-generation National Polar-orbiting Operational Environmental Satellite System (NPOESS) was created by the Presidential Decision Directive/National Science and Technology Council (NSTC)-2 of May 5, 1994, that merged the military and civil meteorological programs into a single program.[1] Within NPOESS, the National Oceanic and Atmospheric Administration (NOAA) is responsible for satellite operations, the Department of Defense (DOD) is responsible for major acquisitions, and the National Aeronautics and Space Administration (NASA) is responsible for the development and infusion of new technologies.

In 2000, the NPOESS program anticipated purchasing six satellites for $6.5 billion, with a first launch in 2008. By November 2005, however, it had become apparent that NPOESS would overrun its cost estimates by at least 25 percent, triggering a Nunn-McCurdy review by the DOD. The results of that review were announced in June 2006;[2] among the notable changes in the "certified" NPOESS program were the following:

- The planned acquisition of six spacecraft was reduced to four.
- The planned use of three Sun-synchronous orbits was reduced to two, with data from the European Meteorological Operational (MetOp) satellites provided by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) providing data for the canceled mid-morning orbit.
- The launch of the first spacecraft, NPOESS C1, was delayed until 2013.
- Several sensors were canceled (in common parlance, "demanifested") or degraded ("descoped") in capability as the program was refocused on "core" requirements related to the acquisition of data to support numerical weather prediction. "Secondary" (non-core) sensors that would provide crucial continuity to certain long-term climate records, as well as other sensors that would have provided new measurement capabilities, were not funded in the certified NPOESS program.

Since the 1970s, NOAA has operated geostationary satellites that provide images and data on atmospheric, oceanic, and climatic conditions over the continental United States and Hawaii from ~22,000 miles above the equator. NOAA's next generation of geostationary weather satellites will commence with the launch of GOES-R in 2015.[3] Originally, plans for this series included four satellites—GOES-R through GOES-U. However, in September 2006, following significant cost growth

[1] Presidential Decision Directive/NSTC-2, "Convergence of U.S.-Polar-Orbiting Operation Environmental Satellite Systems" May 5, 1994, available at http://www.ipo.noaa.gov/About/NSTC-2.html.

[2] See U.S. House of Representatives Committee on Science, Hearing Charter, "The Future of NPOESS: Results of the Nunn-McCurdy Review of NOAA's Weather Satellite Program," June 8, 2006, available at http://gop.science.house.gov/hearings/full06/June%208/charter.pdf.

[3] Following program changes in September 2006, it was announced that launch of the first spacecraft in the GOES-R satellite series would be delayed until December 2014. However, a reduction in funds included in the FY 2008 enacted budget resulted in an additional delay until April 2015. See Chapter 4, "Procurement, Acquisition and Construction," in *NOAA FY 2009 Budget Summary*, available at http://www.corporateservices.noaa.gov/~nbo/09bluebook_highlights.html.

and estimates that the total program cost would nearly double,[4] NOAA reduced the scope of the program, removed a key instrument on the spacecraft, the Hyperspectral Environmental Suite (HES),[5] and revised the procurement process so that only two satellites are guaranteed.[6]

These events prompted a request from NASA and NOAA for two National Research Council (NRC) efforts. The first, a workshop titled "Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft" and held in Washington, D.C., on June 19-21, 2007, gave participants an opportunity to discuss options to recover measurement capabilities, especially those related to climate research, that were lost as a result of the Nunn-McCurdy actions and the cancellation of the HES on GOES-R. Some 100 scientists and engineers from academia, government, and industry attended the workshop, commenting on a draft mitigation plan developed by NASA and NOAA[7] as well as exploring options not included in the NASA-NOAA report. A prepublication version of the workshop report (NRC, 2007a) was released in October 2007.

The second NRC effort, a study documented in the present report, builds on the information gathered at the June 2007 workshop. In their request for this study (Appendix A), NASA and NOAA asked that a committee of the NRC "prioritize capabilities, *especially those related to climate research,* that were lost or placed at risk following recent changes to NPOESS and the GOES-R series of polar and geostationary environmental monitoring satellites" [emphasis added].

The Committee on a Strategy to Mitigate the Impact of Sensor Descopes and Demanifests on the NPOESS and GOES-R Spacecraft understands "climate" to be, "the statistical description in terms of the mean and variability of relevant measures of the atmosphere-ocean system over periods of time ranging from weeks to thousands or millions of years." (Climate Change Science Program and the Subcommittee on Global Change Research, 2003, p. 12). In the present study, the committee primarily considered climate related physical, chemical, and biological processes that vary on interannual to centennial timescales. It is also important to note that the committee did not a priori assume a longer-duration measurement record would be assigned a higher priority than a shorter-duration measurement record. Instead, the committee considered each measurement's value to climate science in a more comprehensive sense as described in the Prioritization Process section below. The committee interprets the information needed for climate research broadly to be that which enables:

- Detection of variations in climate (through long-term records),
- Climate predictions and projections,[8] and

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[4] The cost growth resulted in part from the risk reduction achieved by a deliberate shift from a 50 percent cost probability to the more conservative 80 percent probability, based on lessons learned from NPOESS.

[5] The Hyperspectral Environmental Suite consisted of two components: an advanced hyperspectral sounder and a coastal waters imager. The hyperspectral sounder was intended to greatly advance current operational geostationary sounding capability; its cancellation will instead end the long-term geostationary sounding record started by GOES-I. The coastal waters imager component was planned primarily to benefit coastal monitoring, management, and remediation applications.

[6] Oversight Hearing on the Government Accountability Office Report on NOAA's Weather Satellite Program Before the Committee on Science, U.S. House of Representatives, September 29, 2006, available at http://science.house.gov/publications/hearings_markups_details.aspx?NewsID=1194.

[7] Outlined in a presentation titled "Mitigation Approaches to Address Impacts of NPOESS Nunn-McCurdy Certification on Joint NASA-NOAA Climate Goals," available at http://www7.nationalacademies.org/ssb/NPOESSWorkshop_Cramer_NRC_06_19_07_final.pdf and also reprinted in Appendix C of the June 2007 workshop report. A final version of the NASA-NOAA report has not been released; a widely cited December 11, 2006, draft was posted by Climate Science Watch at http://www.climatesciencewatch.org/file-uploads/NPOESS-OSTPdec-06.pdf.

[8] Prediction (climate) is a probabilistic description or forecast of a future climate outcome based on observations of past and current climatological conditions and quantitative models of climate processes (e.g., a prediction of an El Nino event) and projection (climate) is a description of the response of the climate system to an assumed level of future radiative forcing. Changes in radiative forcing may be due to either natural sources (e.g., volcanic emissions) or human-induced causes (e.g., emissions of greenhouse gases and aerosols, or changes in land use and land cover).

- Improved understanding of the physical, chemical, and biological processes involved in climate variability and change.

In performing its prioritization, the committee was cognizant of the scientific importance of maintaining long-term records of climate forcing *and* improving understanding of the climate system through starting or continuing records of climate responses. It also recognized the challenges of finding an appropriate balance between observations of climate forcing and response on the one hand, and sustained observations/"monitoring" and improved "process" understanding on the other. The committee notes that its interpretation of the research agenda for climate-related issues is consistent with the five goals of the U.S. Climate Change Science Program (Box S.1).

BOX S.1 Goals of the U.S. Climate Change Science Program

Goal 1: Improve knowledge of Earth's past and present climate and environment, including its natural variability, and improve understanding of the causes of observed variability and change.
Goal 2: Improve quantification of the forces bringing about changes in Earth's climate and related systems.
Goal 3: Reduce uncertainty in projections of how Earth's climate and related systems may change in the future.
Goal 4: Understand the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes.
Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.

SOURCE: The U.S. Climate Change Science Program Factsheet, available at http://www.climatescience.gov/infosheets/factsheet3/CCSP-3-StratPlanOverview14jan2006.pdf.

APPROACH TO AND SCOPE OF PRIORITIZATION

Conducted during its December 17-19, 2007, meeting, the committee's prioritization of capabilities lost in program restructuring was guided by the following overarching principles:

- The objective of the committee's deliberations would be to prioritize for the restoration of *climate* capabilities. For example, although a sensor with the capability to improve resolution of fast climate processes is of interest to both the weather forecasting and the climate research communities, it is the value to the latter that would inform the committee's ranking.
- The particular strategy for recovery and the cost of recovery of a measurement/sensor would not be a factor in the ranking.[9]
- Measurements/sensors on NPOESS would not be ranked against measurements/sensors on GOES-R; however, the criteria used in ranking measurements/sensors for either program would be identical.
- When it was relevant, the measurement objectives of a particular sensor, and not the sensor itself, would be the basis for consideration. Thus, for example, members of the committee considered the

Climate "projections" are distinguished from climate "predictions" in order to emphasize that climate projections depend on scenarios of future socioeconomic, technological, and policy developments that may or may not be realized. (Climate Change Science Program and the Subcommittee on Global Change Research, 2003, p. 12).

[9] The committee did not have access to the ongoing NASA-NOAA study for OSTP that is examining the cost of various recovery strategies.

importance of radar altimetry to climate science, rather than the importance of the particular implementation of this capability on NPOESS, that is, the ALT instrument.

Prior to the meeting, one or more committee members with the requisite expertise was assigned the task of preparing a detailed review of the issues associated with the descoping or demanifesting of a particular NPOESS or GOES-R measurement capability, guided by questions 1 through 9, below. These questions, which were developed at the committee's first meeting, follow from the committee's interpretation of what constitutes climate science and the associated requirements for climate observations (see above); they allow a prioritization across the diverse information requirements for climate science, for example, long-term measurements, new measurements, measurements of climate forcings and responses, measurements to improve scientific understanding and reduce key uncertainties, and measurements to improve climate predictions. The questions are also consistent with the ranking criteria employed by the panels of the NRC Earth science and applications from space decadal survey (NRC, 2007), although in that study societal benefits and cost considerations were included as ranking factors.[10]

By design, the questions were open-ended in order to provoke a more nuanced discussion of the value of the measurements. For example, rather than merely listing the duration of the measurement records at risk as a proxy for value, the committee considered the value of a long-term record in a more holistic manner via questions 1 and 5, which in turn prompted an in-depth exploration of the value of the long-term record, the impact of the record on global climate studies, the relative impact/consequences of a gap in the record, the maturity of related data assimilation, and sensor heritage. Such an analysis was considered important in the prioritization process in order to appropriately balance the need to continue very-long-duration measurements with shorter-duration measurements. The former would benefit with better scores for measurement/sensor maturity and the value of maintaining the long-term record. The latter measurements, although perhaps less mature, might result in greater consequences associated with a prospective measurement gap (for example, those related to climate forcing/response parameters with larger uncertainties for which longer trend data can greatly constrain future climate predictions).

1. To what extent are the data used both to monitor and to provide a historical record of the global climate? Is there a requirement for data continuity? If so, discuss the consequences of a measurement gap.
2. To what extent is this measurement important in reducing "uncertainty"—for example, in reducing error bars in climate sensitivity forcing and monitoring? In making these judgments, refer also to the priorities of the Climate Change Research Program.
3. Consider the importance of the measurement's role in climate prediction and projections (forcing/response/sensitivity).
4. To what extent is the measurement needed for reanalysis?
5. Describe the measurement's maturity—for example, its readiness to be assimilated into a particular model(s)—and its heritage. If discussing a sensor, discuss its technical maturity and heritage.
6. Are other sensors and ancillary data required to make the measurement useful? Is this measurement unique? Are there complementary international sensors? If so, please list them and assess their capabilities. Discuss any data issues you may be aware of.
7. To what extent are the data used by, for example, the Intergovernmental Panel on Climate Change and the Climate Change Science Program (in developing synthesis and assessment products)?
8. Provide a qualitative assessment of the measurement's role in contributing to an overall improved understanding of the climate system and climate processes.
9. To what extent does the measurement contribute to improved understanding in related disciplines?

[10] See Box 2.2 in *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (NRC, 2007), p. 40.

Following each reviewer presentation, committee members actively discussed the measurement objective under consideration in relation to each of the nine questions. *The committee's prioritization was developed on the basis of numerical scoring of the importance of each measurement capability to the needs of the climate research community (questions 1-8) and the importance of the measurement to related disciplines (question 9). Each of the responses to questions 1 through 9 was given equal weight in determining an overall ranking.*[11]

The committee had extensive discussions regarding whether a simple average of committee member rankings of the responses to questions 1 through 9 should be used for an overall ranking, or whether rankings with respect to particular questions should be given more weight. In part because there was no consensus among committee members on how a particular weighting scheme might improve what was already a subjective evaluation (in mapping the study statement of task to the questions, and in assigning individual numerical rankings for each question), the committee determined that the use of an unweighted average was advisable. Given that the committee was not provided any information concerning costs, relative or absolute, for any of the proposed mitigations, its prioritization of measurement capabilities was based entirely on climate science value as determined by consideration of the nine questions above. Lacking the information by which to determine the financial implications of its recommendations, the committee did not include implementation costs in its rankings. The committee notes, however, that had costs been provided, a more far-reaching set of recommendations might have been developed in which cost/benefit was taken into consideration. It is also important to recognize that important nonscientific factors were not, by design, part of the committee's analysis.

Before restructuring, each of the lost or degraded measurement capabilities had been considered both practicable and of high importance. In the case of NPOESS, a tri-agency under-secretary-level executive committee provides overall program direction and ensures that both civil and national security requirements are satisfied.[12] GOES-R requirements had been established by NOAA following a formal process that determined and prioritized user requirements; various senior management committees oversaw this process.[13] As is evident in the "Highlights of Analysis" sections in Chapter 3, the committee also found great merit in each of the climate-related measurement capabilities under consideration. However, given that a wholesale reversal of the program changes was not feasible, it became the committee's difficult task to provide a prioritized set of recommendations for restoration of climate measurement capabilities.

SUMMARY OF PRIORITIES AND MITIGATION OPTIONS

The committee prioritized all of the climate-related measurement capabilities that were lost or diminished as a result of NPOESS and GOES-R program restructuring rather than limiting its recommendations to the demanifested sensors as was done in the NASA-NOAA draft report prepared for OSTP.[14] The committee's approach is consistent with input received from the community as part of the NRC's June 2007 workshop. Specifically, with respect to changes in the NPOESS program, the committee considered:

- Aerosol properties and the Aerosol Polarimetry Sensor (APS),

[11] The committee was aware of a similar prioritization exercise conducted by NASA and NOAA in late 2006/early 2007. NASA and NOAA reached a somewhat different prioritization, which the present committee attributes in large part to their giving additional weight to the factors noted in question 1, that is, measurement continuity and the importance of avoiding a data gap.

[12] Presidential Decision Directive/NSTC-2, "Convergence of U.S.-Polar-Orbiting Operation Environmental Satellite Systems," May 5, 1994, available at http://www.ipo.noaa.gov/About/NSTC-2.html.

[13] See Jim Gurka, "The Requirement Process in NOAA GOES-R Mission Definition," April 12, 2007, available at http://osd.goes.noaa.gov/documents/Requirements_Process.pdf.

[14] See footnote 7 above.

- Earth radiation budget and the Clouds and Earth's Radiant Energy System/Earth Radiation Budget Sensor (CERES/ERBS),
- Hyperspectral diurnal coverage and the Cross-track Infrared Sounder (CrIS),
- Microwave radiometry and the Conical Scanning Microwave Imager/Sounder (CMIS),
- Ocean color and the Visible/Infrared Imager/Radiometer Suite (VIIRS),
- Ozone profiles and the Ozone Mapping and Profiler Suite-Limb (OMPS-L) sensor,
- Radar altimetry and the ALT sensor, and
- Total solar irradiance and the Total Solar Irradiance Monitor (TIM)/spectrally resolved irradiance and the Solar Spectral Irradiance Monitor (SIM).

With respect to the changes in the GOES-R program, the committee considered:

- Geostationary coastal waters imagery and the HES-CWI Sensor, and
- Geostationary hyperspectral sounding and the HES Sensor.

As a result of the prioritization process, the measurements and sensors listed above are divided approximately into four groups, which the committee designates, in descending order of priority, as Tier 1 through Tier 4. These are shown in priority order in Figure S.1. *As noted above, sensors from the NPOESS and GOES-R programs were not prioritized head-to-head.* However, it can be roughly stated that considering climate science contributions alone, geostationary hyperspectral sounding compares to the NPOESS capabilities prioritized as Tier 2, and coastal waters imagery falls into Tier 4.

After completing the relative prioritization, the committee considered a wide range of options for recovery of the lost capabilities, including the remanifesting of sensors onto NPOESS platforms, accommodation of sensors on free flyers or flights of opportunity, and the use of formation flight to combine multiple, synergistic, measurement types without incurring the cost, complexity, and risk of large facility-class observatories. The committee's recommendations for mitigation recovery of the lost capabilities are detailed in the main text and are summarized in Table S.1.

The color coding used in Figure S.1 and Table S.1—green, yellow, blue, and pink shading to indicate Tier 1, Tier 2, Tier 3, and Tier 4 prioritization, respectively—is used as an interpretive aid in the main text.

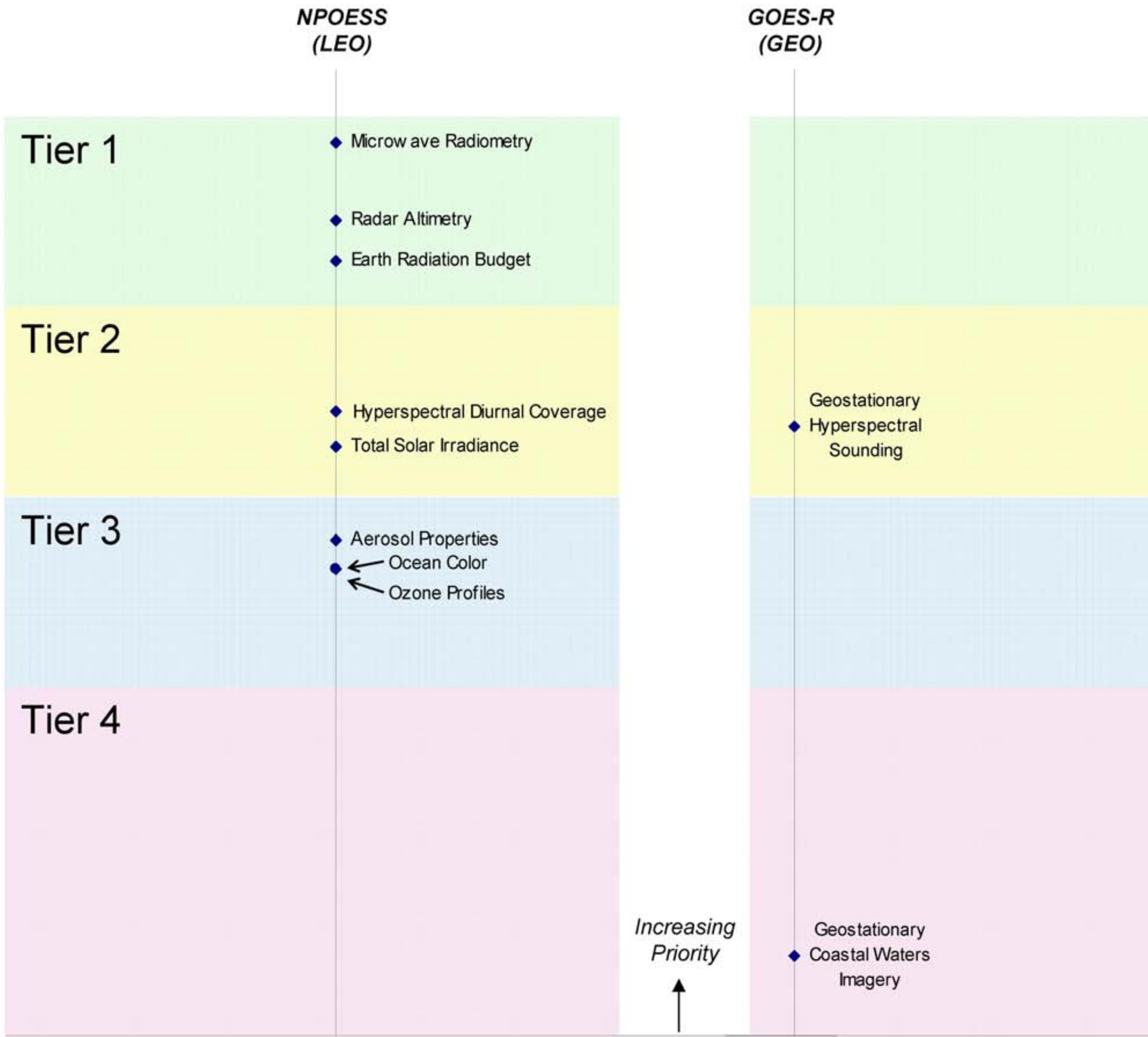

FIGURE S.1 Graphical depiction of overall rankings, showing the clustering of scores into what the committee defined as Tiers 1-4, for recovery of both NPOESS (low Earth orbit) and GOES-R (geostationary Earth orbit) lost or degraded climate capabilities.

TABLE S.1 Summary Recommendations for Mitigation of Lost or Degraded Climate Capabilities

Lost or Degraded Climate Capability in NPOESS Low Earth Orbit	**Recommendation**
Tier 1	
Microwave Radiometry	• NASA and NOAA should initiate a study as soon as practicable to address continuity of microwave radiometry and to determine a cost-effective approach to supplement the AMSR-2, carried on the Japanese spacecraft GCOM-W, with another microwave radiometer of similar design. The agencies should also consider the feasibility of manifesting a microwave radiometer on a flight of opportunity or free flyer to cover the microwave radiometry gap anticipated with a delay in accommodation of MIS until NPOESS C2. • The agencies should provide funding for U.S. participation in an AMSR-2 science team to take full advantage of this upcoming microwave radiometer mission. • The NPOESS Integrated Program Office should continue with its plans to restore a microwave sounder to NPOESS C2 and subsequent platforms, with an emphasis on the science user advisory group's priorities 1 through 3 (core radiometry, sounding channels, and soil moisture/sea surface temperature). • NASA and NOAA should devise and implement a long-term strategy to provide sea-surface wind vector measurements. The committee has significant concerns in the planned reliance on a polarimetric radiometer for obtaining this measurement; instead, the preferred strategy is timely development and launch of the next-generation advanced scatterometer mission, that is, the Extended Ocean Vector Winds Mission (XOVWM) recommended in the NRC decadal survey *Earth Science and Applications from Space* (NRC, 2007b).
Radar Altimetry	A precision altimetry follow-on mission to OSTM/Jason-2 (i.e., Jason-3) should be developed and launched in a time frame to ensure the necessary overlap between missions. The agencies' long-term plan should include a series of precision altimetry free flyers in non-Sun-synchronous orbit designed to provide for climate-quality measurements of sea level.
Earth Radiation Budget	The committee reiterates the recommendation of *Earth Science and Applications from Space* decadal survey to manifest the CERES FM-5 on NPP to mitigate the risk of a data gap. The agencies should further develop an ERB instrument series and provide for subsequent flights on platforms in Sun-synchronous orbit to continue the Earth radiation budget long-term record.
Tier 2	
Hyperspectral Diurnal Coverage	The CrIS/ATMS instrument suite should be restored to the 05:30 NPOESS orbit to provide improved hyperspectral diurnal coverage and support atmospheric moisture and temperature vertical profile key performance parameters.
Total Solar Irradiance	The agencies should consider use of an appropriate combination of small, low-cost satellites and flights of opportunity to fly TSIS (or at least TIM) as needed to ensure overlap and continuity of measurements of total solar irradiance.
Tier 3	
Aerosol Properties	• NASA should continue its current plan to fly the APS on Glory. • NASA and NOAA should continue to mature aerosol remote sensing technology and plan for the development of operational instruments for accommodation on future platforms and/or flights of opportunity.
Ocean Color	• The NPOESS Integrated Program Office should consider any practical mechanisms to

	improve VIIRS performance for NPP and ensure all that specifications are met or exceeded by the launch of NPOESS C1. • The agencies should ensure that adequate infrastructure is in place for post-launch calibration/validation, including oversight by the scientific community, to ensure the production of viable ocean color imagery. • To address reduced sensor coverage, the agencies should work with their international partners toward flying a fully functioning VIIRS or a dedicated sensor on a mission of opportunity in Sun-synchronous orbit. The agencies should also work with international partners to ensure community access to ocean color and ancillary calibration/validation data from international platforms during the likely gap to be experienced prior to launch of NPOESS C1.
Ozone Profiles	The committee supports current agency plans to reintegrate OMPS-Limb on NPP. The agencies should consider the relative cost/benefit of reintegration of OMPS-Limb capabilities for NPOESS platforms carrying OMPS-Nadir based on the degree of integration inherent in the instrument's original design.

Lost or Degraded Climate Capability in GOES-R Geostationary Earth Orbit	**Recommendation**
Tier 2	
Geostationary Hyperspectral Sounding	NASA and NOAA should plan an earliest-possible demonstration flight of a geostationary hyperspectral sounder, supporting *operational* flight in the GOES-T time frame.
Tier 4	
Geostationary Coastal Waters Imagery	Provision for coastal waters imaging should be considered by the agencies based on nonclimate applications.

ELEMENTS OF A LONG-TERM CLIMATE STRATEGY: A WAY FORWARD

The committee has developed and recommends a prioritized, short-term strategy for recovery of crucial climate capabilities lost in the NPOESS and GOES-R program descopes. However, mitigation of these recent losses is only the first step in establishing a viable long-term climate strategy—one that builds on the lessons learned from the well-intentioned but poorly executed merger of the nation's weather and climate observation systems. The key elements of such a long-term strategy are discussed in Chapter 4 and are summarized here.

Sustained Climate Observations

In developing an effective long-term climate strategy, it is critical to consider the similarities in and differences between research, operational, and sustained measurements in order to take advantage of synergies when appropriate while avoiding incompatible observing system requirements. Sustained measurements needed to detect climate trends can, for example, impose tighter requirements for calibration, characterization, and stability, or impose orbit constraints different from what would otherwise be required for operational applications. A long-term climate strategy must provide for the essential characterization, calibration, stability, continuity, and data systems required to support climate applications.

National Policy for Provision of Long-term Climate Measurements

Much of climate science depends on long-term, sustained measurement records. Yet, as has been noted in many previous NRC and agency reports, the nation lacks a clear policy to address these known national and international needs. For example, an ad hoc NRC task group (NRC, 1999b, p. 4) stated as follows:

> No federal entity is currently the "agent" for climate or longer-term observations and analyses, nor has the "virtual agency" envisioned in the [U.S. Global Change Research Program] succeeded in this function. The task group endorses NASA's call for a high-level process to develop a national policy to ensure that the long-term continuity and quality of key data sets required for global change research are not compromised in the process of merging research and operational data sets.[15]

A coherent, integrated, and viable long-term climate observation strategy should explicitly seek to balance the myriad science and applications objectives basic to serving the variety of climate data stakeholders. The program should, for example, consider the appropriate balance between (1) new sensors for technological innovation, (2) new observations for emerging science needs, (3) long-term sustainable science-grade environmental observations, and (4) measurements that improve support for decision makers to enable more effective climate mitigation and adaptation regulations (NRC, 2006). The various agencies have differing levels of expertise associated with each of these programmatic elements, and the long-term strategy should seek to capitalize on inherent organizational strengths where appropriate. Elements of this needed national policy include clear roles and responsibilities for agencies, international coordination, and community involvement in the development of climate data records.

Clear Agency Roles and Responsibilities

In the NRC decadal survey *Earth Science and Applications from Space*, the authors stated, "The committee is concerned that the nation's civil space institutions (including NASA, NOAA, and USGS) are not adequately prepared to meet society's rapidly evolving Earth information needs. These institutions have responsibilities that are in many cases mismatched with their authorities and resources: institutional mandates are inconsistent with agency charters, budgets are not well matched to emerging needs, and shared responsibilities are supported inconsistently by mechanisms for cooperation. These are issues whose solutions will require action at high levels of the federal government" (NRC, 2007b, p. 13). In turn, this prompted one of the report's most important recommendations: "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" (p. 14). **The present committee fully endorses the need for clarified agency roles and responsibilities, consistent with inherent agency strengths, and reiterates this important recommendation of the decadal survey.**

[15] A similar view was expressed in *Adequacy of Climate Observing Systems,* which stated, "There has been a lack of progress by the federal agencies responsible for climate observing systems, individually and collectively, toward developing and maintaining a credible integrated climate observing system" (NRC, 1999a, p. 5).

International Coordination

The committee recognizes the importance of international cooperation in obtaining climate-quality measurements from space; the absence of an internationally agreed upon and ratified strategy for climate observations from space remains an area of grave concern. **The research and operational agencies should coordinate their development, operations, standards, and products with international partners.**

Community Involvement in the Development of Climate Data Records

The NRC has produced a number of reports on the subject of climate data records (CDRs), many having been motivated by concerns over the future availability of satellite-based climate-quality data records. The implied demise of climate-focused satellite observations from NPOESS, a consequence of the Nunn-McCurdy certification, adds to the ongoing concern about the lack of organized commitment to CDR development. It has been stressed in many NRC and other reports that generation of CDRs requires considerable scientific insight, including the blending of multiple sources of data; error analysis; and access to raw data. On the basis of its review of previous NRC studies and its own experience, the committee identified a number of particularly important elements for a sustained long-term program dedicated to developing credible CDRs. These elements are discussed in Chapter 4.

Finally, it is important to note that community concerns about the adequacy of NPOESS for climate research existed even before the 2006 program restructuring. For example, in the 2007 NRC decadal survey *Earth Science and Applications from Space* (NRC, 2007b, p. 263), the report from the Panel on Climate Variability and Change concluded that, "Regardless of the descoping, the NPOESS program lacks essential features of a well-designed climate-observing system."

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COMMITTEE ON A STRATEGY TO MITIGATE THE IMPACT OF SENSOR DESCOPES AND DEMANIFESTS ON THE NPOESS AND GOES-R SPACECRAFT

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Preface

In June 2007, the National Research Council (NRC) held a 3-day workshop, "Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft," in Washington, D.C., to discuss options to recover measurement capabilities, especially those related to climate research, that were lost following a congressionally mandated review completed in June 2006 (Nunn-McCurdy certification[1]) of the NPOESS program and the September 2006 cancellation of the HES sensor on GOES-R. Some 100 scientists and engineers from academia, government, and industry attended the workshop, which gave participants a chance to consider and comment on a mitigation plan developed by NASA-NOAA as well as to explore options that were not included in the NASA-NOAA study. An NRC report on the workshop proceedings was released in prepublication form in September 2007.[2] By design, that report did not present findings or recommendations.

Shortly before the workshop, NASA and NOAA requested that a committee of the NRC separate from the workshop organizing panel be formed to carry out a short follow-on study that would perform the following tasks (see Appendix A):

1. Prioritize capabilities, especially those related to climate research, that were lost or placed at risk following recent changes to NPOESS and the GOES-R series of polar and geostationary environmental monitoring satellites; and
2. Present strategies to recover these capabilities.

The present report, written by the ad hoc Committee on a Strategy to Mitigate the Impact of Sensor Descopes and Demanifests on the NPOESS and GOES-R Spacecraft, constitutes the NRC response to this request.

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[1] See U.S. House of Representatives Committee on Science and Technology, Hearing Charter, "The Future of NPOESS: Results of the Nunn-McCurdy Review of NOAA's Weather Satellite Program," June 8, 2006, available at http://gop.science.house.gov/hearings/full06/June%208/charter.pdf.

[2] The workshop report (National Research Council, *Options to Ensure the Climate Record from the NPOESS and GOES-R Spacecraft: A Workshop Report,* The National Academies Press, Washington, D.C., 2008) is reprinted in Appendix B.

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's (NRC's) Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their participation in the review of this report:

Mark R. Abbott, Oregon State University,
Sarah T. Gille, Scripps Institution of Oceanography and University of California, San Diego,
Ralph F. Milliff, Colorado Research Associates,
William B. Rossow, City University of New York,
Thomas H. Vonder Haar, Colorado State University, and
Steven C. Wofsy, Harvard University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Carl Wunsch, Massachusetts Institute of Technology and Michael J. Prather, University of California, Irvine. Appointed by the NRC, they were responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

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APPENDIXES