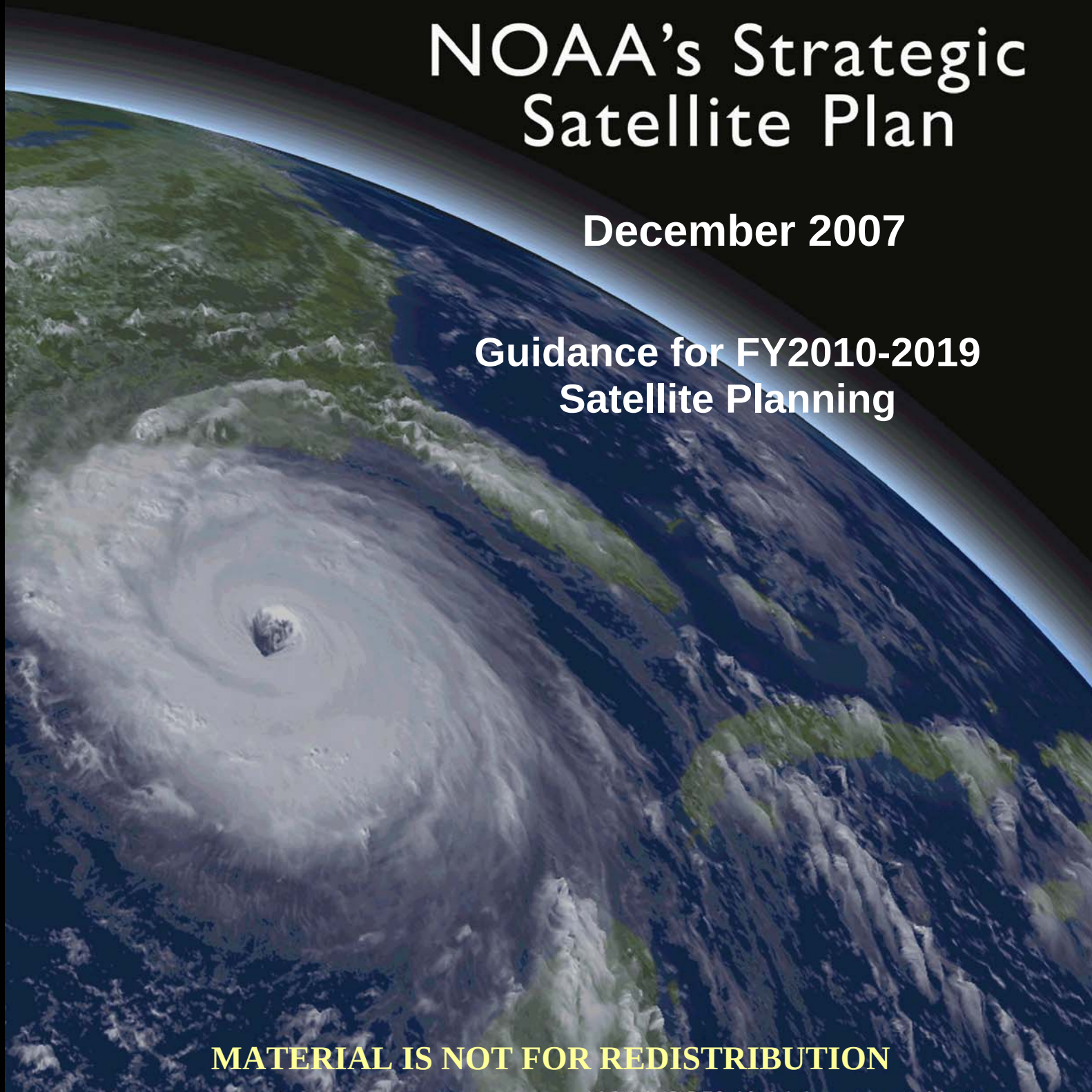
NOAA's Strategic Satellite Plan



December 2007

Guidance for FY2010-2019 Satellite Planning

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NOAA's Strategic Satellite Plan
Fiscal Year 2010-2019

December 2007

On the Front and Back Covers

(front) NOAA Satellite Measurements yield important insights into tropical cyclone structure.

(back) NOAA's early warnings depend on operational and research satellites, and other NOAA platforms.

Hurricane Katrina from NOAA GOES-12
1 kilometer visible image
Courtesy of NOAA/NESDIS Visual Lab

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Strategic Satellite Plan Updates

NOAA uses a five-year planning cycle for program planning for funding resources. Figure i illustrates NOAA's Overview of the budgeting system.

	Planning	Programming	Budgeting	Execution
Purpose: What NOAA…	Should do	Can do	Will do	Does
Steps	Strategic & Annual Planning	Program Review & Development	Formulation & Justification	Program Performance & Financial Management
Lead	Program Planning & Integration (PPI)	Program Analysis & Evaluation (PA&E)	NOAA Budget Office (NBO)	Deputy Under Secretary / NOAA Budget Office (DUS/NBO)

Figure i: PPBES Planning Phases

The NOAA Strategic Satellite Plan will provide guidance for satellite planning and programming starting in FY10. NOAA's Strategic Satellite Plan will be updated annually within the schedule of the PPBES Planning Cycle (see Figure i), for the proceeding planning phase. This requires annual updates, program coordination, and document approval by April of each year. From April to February, the plan will be updated in preparation of the start of the next cycle.

During each fiscal year (see Figure ii), multiple activities take place for different five year periods. During any one year, planning, programming, budgeting, and execution occur. For instance, during the execution period for FY 2007, the planning then programming phases for FY 2010-2014 occurs March through August and September through January. In addition, the budgeting phase for FY 2009 starts in February 2007 and continues through FY 2008.

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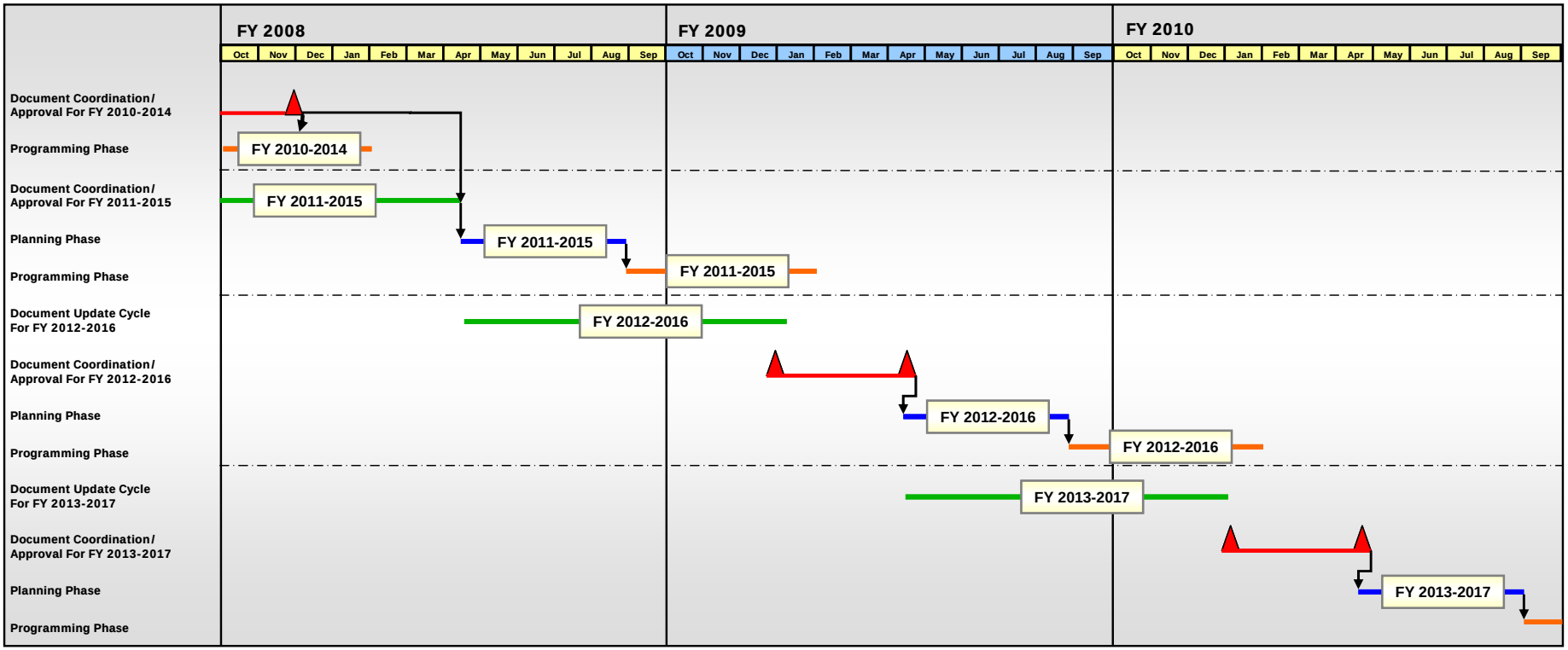
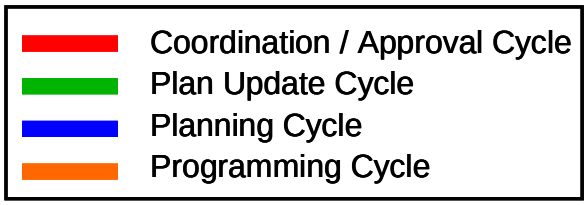


Figure ii. NOAA's Strategic Satellite Plan Master Calendar



Executive Summary

At the direction of the Undersecretary of Commerce for Oceans and Atmosphere and the National Oceanic and Atmospheric Administration (NOAA) Administrator, a cross-cutting team (multiple disciplines) developed a 10-year strategic satellite plan to examine NOAA satellite investment opportunities, ensure continuity of the space-borne observations, and sustain a robust ground segment and infrastructure. This plan seeks the sustainment and continuance of the NOAA's satellite services at today's operational capability level, an investment in enhancements and optimizations of satellite sensors to improve constellation performance and capability, and to improve satellite services (e.g., algorithm development, product processing and distribution). This plan focuses on the period from FY2010-2019. Data from a minimum of two decades were projected and analyzed to allow adequate planning periods for acquisitions, modifications, enhancements, and continued service. This plan, along with annual updates, will provide the long-range program objective and guidance for NOAA satellite systems throughout the Planning, Programming, Budgeting, and Execution System (PPBES) planning and programming phases. NOAA's PPBES will provide fiscal guidance on an annual basis. NOAA will develop its environmental satellite program by advancing system designs, adding new capability sensors (e.g., lightning mapper), and fostering cooperation with other key government and international partners to support NOAA's diverse mission to "understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs." This plan ensures continuity of measurements where and when appropriate, provides fiscally responsible estimates of the planned capabilities, and extends NOAA's capabilities to improve our nation's ability to protect lives and property.

Satellite Collection

NOAA currently acquires environmental observations and achieves continuity of operations through a constellation of NOAA and other agencies' satellites. The backbone of the NOAA satellites includes the Geostationary Operational Environmental Satellite (GOES) and Polar-orbiting Operational Environmental Satellite (POES) systems. Key assumptions of this strategic satellite plan included: NOAA's support for continuing the GOES and POES systems; NOAA's partnerships with other agencies (National Aeronautics and Space Administration [NASA] and Department of Defense [DoD]); and NOAA's foreign partnerships (European Organisation for the Exploitation of Meteorological Satellites [EUMETSAT], Japan Aerospace EXploration Agency (JAXA) and Centre National d'Etudes Spatiales [CNES]). This includes auxiliary functions with the satellite systems: Data Collections Systems (DCS), Search And Rescue Satellite (SARSAT), Emergency Managers Weather Information Network (EMWIN), and direct broadcast. Data supplied to NOAA by its partners complements NOAA's operational data suite to expand its ability to monitor and forecast environmental change. NOAA's participation in the Global Earth Observation System of Systems (GEOSS) and evolution into a NOAA architecture are designed to be consistent with the Global Earth Observations Integrated Data Environment (GEO-IDE). NOAA's view of GEO-IDE is a "system of systems"—a framework that provides effective and efficient integration of NOAA's many quasi-independent systems (platforms) and individually addresses the diverse mandates of resource management, weather forecasting, safe navigation, disaster response, and coastal mapping.

GOES and POES are operated to provide critical atmospheric, oceanic, climatic, solar and space data and images that are used to protect life and property across the United States. NOAA's

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geostationary satellites, with the next generation GOES-R series planned for launch beginning in 2014, continuously monitor the same longitudes from two distinct orbits to provide coverage across the eastern United States, most of the Atlantic Ocean, the western United States, Central/South America, and the Pacific Ocean basin. The Polar Acquisition Program consists of NOAA's POES System and the National Polar-orbiting Operational Environmental Satellite System (NPOESS) orbiting from north to south across the poles in three orbits planes to provide global coverage. POES is NOAA's current operational polar system and has one satellite remaining to launch in the current series, while NPOESS is the follow-on polar-orbiting satellite system. In addition, both types of satellites provide platforms for solar observations, data collection, search and rescue, and other environmental observations.

Analysis

Development of this plan began with the review of NOAA's mandates, missions, requirements, studies, and recommendations from relevant scientific community documents. Additionally, current instrument performance was assessed to determine if the identified measurements will satisfy requirements documented in the Consolidated Observation Requirements List (CORL). The CORL is the single, NOAA-wide operational observation requirements database.

Next, a three-day technical exchange working group was convened with invitees from across NOAA and key representatives from our NASA partners. During the workshop, the future of NOAA satellite observational requirements was explored to provide a better understanding of how satellites will acquire environmental information in the future. The second part of the workshop explored the capabilities and potential requirement candidates of future satellite instrument families.

In addition, the analysis took note of significant events impacting satellite planning (e.g., Nunn-McCurdy, interagency assessments, Analysis of Alternatives [AoA], and the National Research Council's [NRC's] *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*) that shaped and influenced NOAA's environmental observations and satellite systems. Two of the events affected the polar-orbiting system, one affected the geostationary orbiting system, and one affected both systems.

Nunn-McCurdy. The NPOESS system was certified by the Congressionally-mandated Nunn-McCurdy Act on June 5, 2006. NPOESS is managed by the tri-agency Integrated Program Office (IPO) utilizing personnel from the Department of Commerce, DoD, and NASA, and was required to be re-certified by the Nunn-McCurdy process in accordance with U.S. law due to DoD cost overruns exceeding 25 percent. This certification placed a priority on the continuity of operational weather measurements at the expense of climate and space weather measurements. The climate sensors for ozone, aerosol, earth radiation budget, total solar irradiance, and altimetry were de-manifested from the NPOESS. The space weather sensors were reduced from a suite of six to a suite of three and remain on only one of the two remaining orbit planes.

Interagency Assessment: NOAA and NASA conducted a joint assessment to review and assess possible mitigation approaches to address the climate observation impacts based on the NPOESS Nunn-McCurdy certification. A cost study was initiated to examine options for re-manifesting sensors onto NPOESS, including costs for development and stewardship of climate data records. The cost to re-integrate de-manifested sensors onto spacecraft was included in the NPOESS budget. A parallel NASA cost-study of potential gap-filler missions was also undertaken. In

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addition, NOAA continues to work with the Office of Science and Technology Policy to determine a recommended path forward for the climate and space environment measurements.

Analysis of Alternatives (AoA): Due to cost and risk challenges, the GOES-R program office decided to de-manifest the advanced sounding and coastal water imaging sensors (Summer 2006). As a result of this decision by NOAA, an AoA team studied and estimated the cost of the alternatives to meet the requirements originally satisfied by these instruments. The AoA determined an operational advanced sounder was needed to satisfy NOAA requirements and recommended a demonstration instrument. Upon proving the capability, the sounder instrument would be added as an operational instrument on the GOES-T satellite. The AoA team recommended a series of low Earth orbiting satellite sensors to address the coastal waters requirement.

NRC Decadal Survey: The final event to influence NOAA satellites was a report by the National Research Council Committee on Earth Science and Applications from Space. The committee's final report, "*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*" is hereafter called the Decadal Survey. The Decadal Survey represents the broad scientific community views of the most important measurements for the next decade. It also identifies important policy issues that must be addressed if the nation is to maintain and grow its scientific leadership role on space-based observations. The report directly addresses the loss to the nation due to NPOESS and GOES-R budget restructuring and re-scoping. It promotes cross-agency planning to avoid "observational capability gaps" and provides details on important benefits that could be accrued given appropriate resources. The Decadal Survey recommended NOAA operate ocean surface vector wind, Global Positioning Satellite (GPS) Radio Occultation (GPSRO), and solar/Earth radiation characteristics missions. This plan acknowledges the report findings and has recommended feasibility studies, including benefit analysis to determine the appropriate sensing platforms.

Results

The team's analysis included comparing the findings to the current set of satellite requirements in the CORL and planned missions. More than 800 mission-critical requirements were identified within the CORL. These requirements were grouped into 23 measurement areas and cross-referenced to their respective instrument suites with associated timelines to assess current mission sustainment. As a result of this analysis, the planned continuity and capability gaps were identified. These measurement areas were further evaluated against NOAA's satellite program (including operational and acquisition programs) to determine if the requirements were being *met*, *predominantly met*, or *not met* based on temporal, spatial, spectral, or orbit deficiencies. Results from the cross-referencing analysis indicated met, predominantly met, and unmet requirements as follows:

Met Requirements—Satellite observation data meets or will meet spatial, spectral, orbital plane definition, and/or temporal resolution requirement attributes for given data record(s) in NOAA polar and geostationary orbits.

- *Lightning*: A new capability to meet user's requirements will be added as the Geostationary Lightning Mapper (GLM) on the GOES-R satellite scheduled for launch in 2014.

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Predominantly Met Requirements—Satellite observation data meets some spatial, spectral, orbital plane definition, and/or temporal resolution requirement attributes for given data record(s) in NOAA polar and geostationary orbits.

- *Imagery/Radiometry (Visible/Infrared [VIS/IR] and Microwave [MW])*: Future satellite imaging systems require the spatial and temporal resolution appropriate to the observed phenomena. Currently, the GOES satellites are meeting historical geostationary requirements. However, the planned GOES-R advanced imager will have the spatial and spectral bands relevant for the depiction of rapidly developing small-scale weather events. For polar satellites, the VIS/IR and MW imagery satisfies the long-range forecasting requirements in two of the three polar orbits. Due to the removal of a third satellite orbital plane for NPOESS (Nunn-McCurdy, 2006), DoD and EUMETSAT will provide measurements in the third polar plane crucial for the 4-hour refresh time requirements; however, these measurements will not meet the spatial or spectral requirements.
- *Atmospheric Temperature Profiles and Atmospheric Moisture Profiles*: The recently launched (2006) GOES-N/O/P sounders provide frequent atmospheric temperature and humidity soundings for improved weather forecasting and now-casting. However, the derived product images that will be provided by the GOES-R Advanced Baseline Imager (ABI) will only meet the temporal sampling requirements. The vertical profiling requirements needed to define boundary layer structures will not be met. The POES satellites are meeting historical requirements from polar orbit. NPOESS sounding technologies will satisfy a more stringent set of validated requirements for vertical profiles.
- *Ocean Surface Vector Winds*: Near-real time satellite ocean surface observations of wind speed and direction support operational marine weather warnings, analysis, and forecasts. These wind speed measurements have a long heritage using passive microwave measurements from the Defense Meteorological Satellite Program's Special Sensor Microwave Imagery Suite. Upon the end-of-life of a NASA research satellite Quick Scatterometer (QuikSCAT) with the SeaWinds instrument, EUMETSAT will provide scatterometry measurements from the Meteorological Operational (MetOp) Advanced Scatterometer (ASCAT) instrument, but at reduced spatial resolution and coverage.
- *Ocean Color*: Validated open ocean chlorophyll concentration requirements will be satisfied with the Visible Infrared Imager Radiometer Suite (VIIRS) on the NPOESS satellite, to be launched in 2013.
- *Space Environment*: Improved space environment measurements to meet user's requirements will be added as the Space Environmental In-Situ Suite (SEISS) on the GOES-R satellite launch planned for 2014. Additional measurements are taken by the Space Environmental Monitor (SEM) on the POES and NPOESS satellites. Geosynchronous measurement requirements are met, polar measurements are partially met, and solar wind and Coronal Mass Ejection (CME) measurements are unmet. The MetOp SEM will provide space weather sensors similar to those on NOAA POES.

Unmet Requirements—An "Unmet" requirement indicates satellite observation data do(es) not meet spatial, spectral, temporal resolution, and/or orbital plane definition requirement attributes for given data record(s). It also encompasses those measurement requirements that are not currently operational without planned or approved acquisitions within the decade for a new capability.

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- Significant enhancement opportunity areas (requirements not in priority order) that would improve NOAA's capability, but are currently unmet are:
  - Aerosols polarimetry
  - Carbon
  - Earth radiation budget
  - Precipitation type
  - Snow depth
  - Solar measurements
  - Coronal mass ejection
  - Albedo
  - Coastal waters/habitat
  - Ice thickness
  - Radio occultation
  - Soil moisture
  - Tropospheric winds
  - Bathymetry
  - Dissolved organic content of seawater
  - Ozone profiles
  - Sea surface height
  - Solar irradiance
  - Solar winds
- Five of these requirements are affected by the five de-manifested climate sensors (Nunn-McCurdy, 2006)
  - Aerosol polarimeter
  - Altimeter (Sea surface height)
  - Earth radiation budget
  - Ozone mapping and profiler suite limb
  - Total solar irradiance sensor

Overall, NOAA satisfies the majority of the current environmental requirements for Earth observation using satellites and other platforms. However, as requirements for Earth observation continue to grow, new sensor technology advancements are needed. This plan supports efforts to ensure cost-effective measurements are taken from satellites to meet new requirements. Table ES-1 illustrates the overall results, when considering the NOAA satellite systems in conjunction with complementary research and international data as a whole, of the 23 measurement areas (see Table ES-1) and identifies the associated gaps, impacts, risks, and required decisions. Detailed operational impacts are in Appendix E and socioeconomic impacts are in Appendix F.

The associated gaps (partially met and unmet requirements) are further broken down into two categories: continuity and/or capability. Continuity gaps represent significant breaks in service of ongoing satellite observation measurements, and capability gaps represent observation requirements not fully met by available or planned satellite measurements.

The assessment assumes that instruments under development will perform as designed. As the programs develop, the final capabilities will be reassessed.

For this initial plan, a subjective risk assessment was completed; for subsequent plans, a more rigorous analysis will be performed. The risk of each gap indicates the anticipated impact and the most likely event of disruption to forecast skills and analysis and reflects the user communities' dependency on the measurement. Probability analysis will be accomplished during feasibility assessment. The risks are defined as follows:

High = High impact to forecast skill, analysis, or outcome with urgency to mitigate given projected gaps.

Moderate = High impact with minimal urgency or moderate impact with urgency to mitigate given projected gaps.

Low = Moderate/Low impact with minimal urgency to mitigate given projected gaps.

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For each risk, quantifiable decision analyses are required in the near-term to mitigate or accept measurement shortfalls in environmental satellite observational capability.

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Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Imagery/Radiometry (VIS/IR)						Mid AM Polar Orbit, MetOp flies AVHRR (current imager) instead of VIIRS (planned imager)	• Improved ability to characterize snow packs, inc. snow water equivalent, snow depth; less accurate water runoff forecasts and reservoir capacity • Less accurate atmospheric column water, cloud liquid water, etc.; Increased NWP forecast skill • Upgraded weather forecasts and precipitation type identification, decreased forecast skill • Discontinuous satellite data measurements; decreased climate trend identification and accuracy	Low	EUMETSAT decision to upgrade to VIIRS-like instrument
Imagery/Radiometry (MW)						Mid AM Polar Orbit, MetOp has no MIS (microwave imager)		Low	No plan to close gap
Atmospheric Temp Profile						GOES & GOES-R have partial profiling capability	High-frequency temperature soundings improve mesoscale weather predictions	Low	Procure GOES T&U with new advanced sounder
Atmospheric Moist Profile						GOES & GOES-R have partial profiling capability	High-frequency moisture soundings improve mesoscale weather predictions	Low	Procure GOES T&U with new advanced sounder
Lightning						New start and operational in 2016	• Severe Weather indicator (cloud-to-cloud and intracloud lightning strikes) • Capability to continuously count and map lightning discharges during both day and night. • Ability to measure Tropical Storm intensity *Enhances current non-satellite ground systems	NA	Award post PDR GOES-R contract for development
Soil Moisture						DMSP SSMIS & NPOESS MIS have partial capability	Improvement to water, energy, and carbon management efficiencies • increased uncertainty in Flood prediction • Increased ability to assess ground moisture/saturation state • Improved irrigation plans	Moderate	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Ocean Surface Vector Winds						ASCAT (EUMETSAT Scatterometry) & MIS (NPOESS) partial capability, require QuikSCAT follow-on	• Upgraded hurricane model initial analysis leading to Increased intensity and forecast accuracy • Upgrades mesoscale model initial analysis; Increases forecast skill	Moderate	New Start Program for Scatterometry

Table ES-1. Measurement Areas Gap Analysis

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Sea Surface Height						Jason 1/OSTM-need continuation	• Ability to provide accurate ocean specification for numerical ocean models, Increased ocean prediction accuracy, and ocean circulation models • Upgraded capacity for predicting hurricane intensity/ocean heat potential; increased hurricane intensity and forecast accuracy • Continued sea level/height satellite record; climate trend identification and accuracy	High	Follow-On Program for Altimetry
Bathymetry						Study altimetry mission options Study three-satellite altimetry mission (2 repeatable orbits, 1 non-Sun-sync non-repeatable orbit)	• Ability to calculate ocean bottom topography • Increases navigation chart accuracy and ocean model predications • Increases accuracy in Tsunami predictions • Upgraded ability to forecast safe maritime passage	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Ocean Color						Lack of technology confidence in initial VIIRS instrument	• Ability to characterize the amount of live biomass (e.g. phytoplankton), turbidity, identify algal blooms, and track plumes • Slow develop a seasonal assessment of chlorophyll and turbidity within the contiguous United States coastal zone	NA	NA
Coastal Water/ Habitat						Commercial buy-study for coastal/event imager	Provides satellite observations for modeling & forecasting capabilities for ecological and biogeochemical processes in coastal ecosystem management • Ability to effectively monitor ecosystem change; increased capability to identify key trends or mitigating actions • Increased ability to quantify measurements; increased habitat prediction system uncertainty	Moderate	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Earth Radiation Budget						NPP/NPOESS C1 w/Ceres, Need follow-on capability	Improvement to global climate change predictions • Continuous satellite record of incoming and outgoing radiation; increased energy balance accuracy and climate trend identification • Upgraded capability for global and mesoscale energy balance; increases mesoscale forecast accuracy and climate trend accuracy	Low	Re-manifest earth radiation budget instrument onto NPOESS C3 and beyond or instrument on Climate Satellite free-flyer

Table ES-1. Continued

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Aerosols						NPOESS demanifested aerosol polarimeter, replace or other satellite	Improvement to global climate change predictions • Improved accuracy of aerosol optical depth; increased forecast accuracies of visibility, pollution impacts, etc. • Ability to get aerosol type and size distribution; Increases accuracy of regional predictions	Moderate	Re-manifest aerosol polarometer instrument onto NPOESS and beyond or instrument on Climate Satellite free-flyer
Ozone						Limb profiler is manifested on NPP NPOESS demanitested limb profiler, replace or other satellite	• Ability to measure ozone profile to compliment the Total Ozone measurement, leading to a increase in the ability to track ozone change and make predictions for public safety • Increased ability to distribute energy vertically in atmosphere; increases forecast skill	Moderate	Re-manifest ozone profile instrument onto NPOESS and beyond or instrument on Climate Satellite free-flyer
Solar Irradiance						NPOESS demanifested, replace or other satellite	• Continuous satellite record of solar constant observations leading to increased energy balance accuracy and related climate trend indentification • Improved capability to determine the global energy balance, Increases regional prediction accuracy	High	Re-manifest solar radiation budget instrument onto NPOESS C3 and beyond or instrument on Climate Satellite free-flyer
Carbon						Study NASA OCO mission or infrared Radiometer	Ability to quantify carbon sources and sinks • Upgrades capability to predict regional ecosystem impacts • Upgrades capacity for understanding carbon climate trends • Increases forecast accuracy for effluents and their impact	High	Feasibility study for the NASA OCO mission, including benefit analysis, to determine sensing platform
Snow Depth						Study multi-frequency radar	Increased prediction capability for water supplies, floods, weather, and climate • Ability to quantify snow depth; impacts flood and run-off prediction accuracy • Improved albedo/extent specifications; reduces albedo and temperature forecast uncertainty	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform

Table ES-1. Continued

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Ice Thickness/Extent						Study ICEsat II or Multi-frequency Radar	Increased ability to estimate the effects of increasing greenhouse gases on the future global climate • Ability to assess ice characteristics • Improved forecast skill for maritime passage • Upgraded climate trend predictions	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Tropospheric Winds						ADM/Aeolus (partial); no planned follow-on	Improved weather (including over ocean) forecast and long-term analysis of systems (including severe storm) development over oceans	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Precipitation type						No capability today, GPM follow-on required	Ability to provide all-weather information about the hydrological cycle such as latent heat release and the affect on storm dynamics, circulation and atmospheric structure • Ability to determine storm characteristics; reduces severe weather and regional forecast uncertainty • Ability to assess mesoscale system characteristics; increased regional forecast accuracy	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Radio Occultation						COSMIC and GRAS partial, require follow-on	Calibration improvements, since GPSRO observations are totally independent of other atmospheric observations and are very precise • Ability to accurately specify temp and moisture profiles near tropopause and stratosphere; Upgrades global and regional model skill • Ability to measure electron density profiles; Increases communications forecast accuracy	Moderate	Participate in COSMIC Follow-on

Table ES-1. Continued

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Space Environment						NPOESS inability to provide all space products (Nunn-McCurdy)	Improve understanding on how to predict changes in the solar atmosphere at the sun, and how they evolve as they expand outward into the solar system and into the Earth's magnetosphere and atmosphere. • Continues one- to three-day warning of potential geomagnetic storms • Ability to measure solar wind upstream of the Earth; Increased forecast accuracy of communications forecasts, magnetic storm predictions, scintillation predictions and hazards to personnel in space	Moderate	Commit to maintain and improve space environmental measurements
Solar Measurements						ACE sensor health in question. ACE has fuel to last to approximately 2019. The instrument needed for space weather alerts is nearing end of life No current plan for L1 operations mission – explore data buys. No ops CME capability	Increased ability to predict geomagnetic storms • Solar and coronal mass ejections can disable satellites and disrupt communication signals • Ability to improve solar warning time for communication/intel satellites, astronaut safety, and polar airline flight safety • Ability to measure solar wind upstream of the Earth; Increased forecast accuracy of communications forecasts, magnetic storm predictions, scintillation predictions and hazards to personnel in space	High	Commit to maintaining and improving space environmental measurements

Table ES-1. Concluded

Investment Opportunity

Upon completing the analysis, it is envisioned that the end-to-end satellite program will meet NOAA's mission and goals (requirements). The initial strategic plan investment objective is the sustainment and continuance of the NOAA's satellite services at today's operational capability level. The second objective is to invest in enhancements and optimizations of satellite sensors to improve constellation performance, and capability, as well as to improve satellite services. To accomplish these objectives, the cost estimates have been broken down into three investment opportunities: Current Program, Extended Program, and Projected Program (Figure ES-1).

Current Program (Budget from FY09 DOC Passback)

- GOES-N/O/P,
- GOES-R/S;
- NOAA-18/N-Prime;
- NPP/NPOESS (C1-C4)

Extended Program (Current Program PLUS)

- NPOESS Follow-on (Estimated Funding): Satellites C5 and beyond
- GOES-R Follow-on (Estimated Funding): Satellites T&U (with Advanced Sounder) plus future satellites

Projected Program (Extended Program PLUS) (Estimated Funding)

- Other Missions
  - Climate instruments Re-manifested,
  - Scatterometry (ocean vector winds),
  - Altimeter (sea surface height), and
  - Radio occultation
- Investment alternatives: Proposed budget for trade studies and analysis of alternatives
  - Determine specific solutions
  - Address unmitigated gaps, new sensor technology, and new system approaches

Figure ES-1: Three Investment Opportunities

NOAA satellite systems must not stagnate. While today's satellites provide more environmental information then ever before, continuous studies and advancement are needed to satisfy unmet requirements to improve severe storm warning lead times and climate forecasts, and meet future requirements. Table ES-2 delineates recommended candidates for trade studies, technology advancements, and system approaches. Candidates in bold font indicate the recommended near-term actions. Remaining candidates (watch items) will be reviewed annually, (1) to determine if they should remain on the list, and (2) if research indicates enough development/advancement to move to a near-term candidate state. NOAA decision makers can use the resulting analysis from these studied candidates to consider new starts, modifications, or no-start determinations.

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TRADE STUDIES	SENSOR TECHNOLOGIES	SYSTEM APPROACHES
Climate Sensors: Re-manifest onto existing spacecraft or free-flying climate satellite) **Ocean Mission Optimization**: combined Jason and Altimeter Mission **Bathymetry**: feasibility of three satellite constellation with one being a non-sun synchronous and non-repeat orbit **Coastal Waters/Habitat**: feasibility **Precipitation Typ**e: determine sensing platform **Space Environment**: Solution set options for the collection of space measurements from various orbits (i.e., L1, Geostationary, Polar, etc.) *Soil Moisture: feasibility* *Snow Depth: feasibility* *Ice Thickness: feasibility* *Tropospheric Winds: feasibility* *Very High Resolution Sensor: Solution set options for ecosystem and special event support*	**Special Event/Coastal Imager** (ACE, HYSPIRI) **3-D Doppler Wind Lidar** **Geo-Microwave** (soundings/stability) **Solar Spectral Irradiance** (CLARREO) **Ozone Profiler** *Far Infrared Monitoring* *Differential Absorption Lidar* *Laser Altimetry* *Radars (LEO/GEO, freq. by application)* *Wide Swath Altimeter* *Climate Reference Sensor* *Bidirectional Radar* *Sensor Integration Opportunities* *Sparse Aperture Techniques*	**Integrated architecture** including IT security and interoperability **Transaction-based archive and access** **Integrated Cal/Val System** **Address instrument phasing** to provide continuity **Apply OSSE and High Performance Computing optimizations** **Data Compression** *Optimum number of satellites/sensors to purchase* *Flexible launch* *Satellite Cross-link (Communication)* *Satellite/instrument configuration and constellations (MEO, Molniya, L1)* **REQUIREMENTS TRANSLATION/ACQUISITION APPROACH** **Commercial/partner instrument launch** **Optimization Studies** (compare satellite with other platforms — space versus ground/ airborne/sea-based platforms)

Candidates in **bold** font indicate the recommended near-term actions. Candidates in *italics* indicate watch items, to be annually reviewed for technology advancement.

Table ES-2. Sensor and System Trades

Each candidate will proceed through the NOAA Technology, Planning and Integration Office (TPIO) and NOAA Observing Systems Council (NOSC) review process.

Implementation

Implementing the strategic satellite plan will require coordinated, time sequenced steps necessary first to ensure continuity of current satellite observation missions and second, to address critical satellite gaps in coverage and performance. These efforts must examine the full range of capability, technical and performance risk, benefit, and cost through a series of well-managed trades/studies and analyses. NOAA must institute these processes by implementing the following four efforts (described in more detail below): set NOAA satellite priorities; complete the NOAA corporate-level actions; ensure Goal Team and system participation; and quantify funding plans.

NOAA will continue developing a satellite system following these near-term fundamental priorities to ensure continuity of existing measurements (when feasible) and to re-manifest climate sensors (where funding and capability exists).

- Add capability to satisfy ocean requirements (considering technical risk and funding).
- Develop Advanced Sounding capability on the next generation of GOES satellites.
- Ensure Space Environment measurements are fully considered.

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- Apply the CORL as the standard for observational measurement requirements

At the corporate-level, NOAA should (1) institutionalize NOAA's satellite program by annually updating the plan and using the PPBES to ensure full NOAA-wide participation and (2) develop processes to complete NOAA-wide measurement prioritization of the mission-critical requirements identified and validated in the CORL.

NOAA Goal Teams and Programs should:

- Ensure requirements are updated and validated in the CORL (Programs).
- Work with algorithm developers, ground systems planners, and archive and access programs to achieve strategic optimization of a GEO-IDE compliant ground system (Goals and Programs).
- Collaborate with the Satellite Sub-Goal to prioritize requirements and weigh options (Goals and Programs).
- Provide feedback about how the satellite plans satisfy requirements.

NOAA funding efforts require the following actions:

- Develop cost profile estimates for satellite missions.
- Identify and provide funds to conduct analyses of alternatives and system feasibility studies.
- Define and analyze research-to-operations transition trades needed to optimize the observation constellation.

Projected actions inherent in the satellite plan include:

- Continue the geostationary and polar orbiting satellite systems.
- Establish Satellite Altimetry Follow-On System with a 2014 launch date (replacement for NASA Jason-1/Ocean Surface and Typography Mission (OSTM) mission).
- Begin "early new start" trade study for Satellite Scatterometry Mission.
- Start negotiations with ESA/EUMETSAT for upgrades to Imagery sensors (VIIRS-like sensors) for follow-on missions.
- Review spacecraft options for each re-manifested climate sensor and the alternative solution for a free flying climate satellite.
- Procure advanced sounding capability for GOES T/S.
- Develop the Integrated NOAA Architecture for satellites.
- Supporting the Archival System (CLASS).
- Support calibrating satellite data from all satellite sources and validating the products derived from the data.
- Procure solar wind and coronagraph measurements and continue efforts to recover reduced space weather capabilities on NPOESS.

Summary

In conclusion, this strategic satellite plan provides NOAA a comprehensive view of the space-based observational realities and challenges facing corporate decision makers for the next two decades. The plan analyzed and synthesized NOAA's most critical satellite requirements while

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evaluating capabilities to satisfy significant Earth observing limitations. This first report on the "state of the NOAA satellite system" provides the foundation for future evaluations and assessments.

Overall, NOAA satisfies a majority of the environmental requirements. However, as sensor technology has advanced, the requirements continue to evolve and will continue to evolve as more cost effective measurements can be made from satellites. The plan addresses requirements effectively satisfied by Earth observing satellites. This plan establishes a baseline for sustaining critical (unique) satellite capabilities well into the next two decades and identified several significant shortcomings of the existing programs and near-term plans, while highlighting alternatives to either complement or mitigate the associated measurement gaps. These significant limitations include (but are not limited to) Coastal Habitat and related Ecosystem measurements. New capabilities are addressed and the plan recommends specific trade studies to evaluate potential evolution of new technologies into the operational programs. NOAA recommends instituting a formal Operational Instrument Improvement Program with NASA for improved research-to-operations transition capability.

As a living document, this plan will be reviewed and supplemented annually to coincide with the appropriate PPBES inject points. NOAA will require this guidance for preparing their Program Operating Plans, the Annual Guidance Memorandum, the Strategic Portfolio, the Satellite Program Plans and associated alternative/adjustment priorities, and the Program Decision Memorandum.

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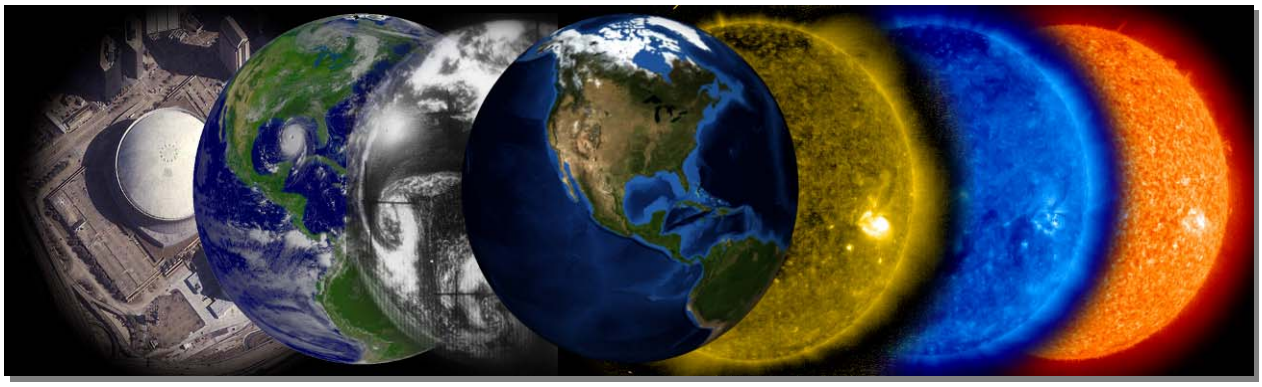

1 Introduction

Satellite observations provide comprehensive perspectives of the Earth, space, and solar environments that are unachievable through other remote and ground systems. These unique measurements provide meteorologists, climatologists, and other scientists with distinct global perspectives for forecasting and analyses that result in the preservation of lives, properties, and natural environments. As satellites have evolved, there has been an increasing reliance and application of satellite observational data. Figure 1 illustrates that over the last four decades, there has been a significant growth in satellite-acquired environmental data across multiple generations of polar-orbiting satellites. Effectively exploiting this ever-increasing usage presents extensive challenges for a satellite-dependent society. Today, National Oceanic and Atmospheric Administration (NOAA) satellites collect more than 20 billion earth observations (pixels) daily. The service rendered by these evolving sentinels supports NOAA's mission of understanding, predicting, and monitoring changes the Earth's surface, atmosphere, oceans, and space/solar environments. NOAA has developed this long-range plan to address the growing need for civil environmental satellite capabilities. This plan addresses NOAA's vision and mission (see Figure 2) in two core areas of national importance: environmental information products and environmental stewardship services.

- ***Environmental Information Products***: NOAA supplies society with information that pertains to the state of the environment, including oceans, land, space, and the atmosphere.
- ***Environmental Stewardship Services***: NOAA serves as the steward of national coastal and marine environments. Coordinating with federal, state, local, tribal, and international authorities, NOAA manages environmental applications by regulating fisheries and marine sanctuaries, as well as protecting threatened and endangered marine species.

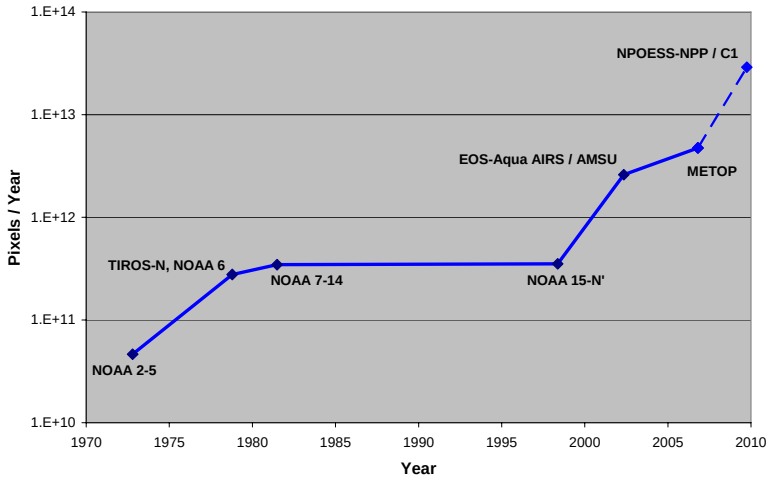

Figure 1. Growth in Polar Orbiting Satellite Observational Capacity

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NOAA VISION

An informed society that uses a comprehensive understanding of the role of the oceans, coasts, and atmosphere in the global ecosystem to make the best social and economic decisions

NOAA MISSION

To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs

NOAA CORE VALUES

People, Integrity, Excellence, Teamwork, and Ingenuity, Science, Service, and Stewardship

Figure 2. NOAA's Vision, Mission Statement and Core Values

Based on stakeholder input and internal assessments of NOAA's mandates and mission, NOAA adopted a structure of four mission goals—Ecosystems, Climate, Weather and Water, and Commerce and Transportation—plus a complementary Mission Support goal, which includes the NOAA Satellite Sub-goal.

Ecosystems: Ensure the sustainable use of resources and balance competing uses of coastal and marine ecosystems, recognizing both their human and natural components

Climate: Understand changes in climate to ensure that society can plan and respond properly

Weather and Water: Provide data and forecasts for weather and water-cycle events, including storms, droughts, and floods and for space weather events

Commerce and Transportation: Provide weather, climate, and ecosystem information to ensure that individual and commercial transportation is safe, efficient, and environmentally sound

Mission Support (Satellite Sub-goal): Provide timely, effective acquisition and delivery of satellite-derived information that supports NOAA's requirements

Using its constellation of operational environmental satellites, NOAA is the trusted source of accurate and objective scientific information in these five areas of national and global importance. Environmental satellites are a major component of NOAA's global efforts to enhance abilities to better observe, understand, and predict impacts by, on, and through our atmosphere, land, space, and oceans. Through NOAA's National Environmental Satellite, Data, and Information Service (NESDIS), NOAA is dedicated to providing high-quality, timely, and beneficial environmental satellite observations to assist in better understanding Earth's environmental interactions. To fulfill its responsibilities, NOAA/NESDIS acquires and manages the nation's operational environmental satellites and—in concert with the National Aeronautics and Space Administration (NASA) and other government or international agencies—leverages research and operational satellite data. This satellite information supports other NOAA offices in the delivery of improved severe-storm warnings, short-and long-term weather forecasts, climate predictions, oceanic and ecosystems analyses, and satellite-aided search and rescue services. NOAA's environmental satellite observations are essential for our national security, provide vital information for aircraft, ships, and facilities around the world, and play a critical role in our nation's economic well-being.

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2 Preparing the Strategic Satellite Plan

2.1 Background

At the direction of the Undersecretary of Commerce for Oceans and Atmosphere and the NOAA Administrator, a cross-cutting team (multiple disciplines) developed this 10-year strategic satellite plan to examine satellite investment opportunities and ensure continuity of the space-borne observations. Although this plan specifically addresses Fiscal Years (FY) 2010–19, data from a minimum of two decades were projected and analyzed to allow adequate planning periods for acquisitions, modifications, enhancements, and continued service. This plan will be updated annually to provide the long-range program objective and guidance for the satellite systems during the PPBES planning and programming phases.

The plan has been reviewed to ensure that there is consistency, entrainment, and continuity with existing satellite plans, recent recommendations, such as the *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond and the Ocean Priorities Research* plan, and decisions/responses affected by those recommendations. In addition, the plan satisfies the nation's environmental observation requirements to understand and predict global, regional, and local environmental conditions, including climate change.

Over the last four decades, environmental satellite observations have evolved from still images of cloud cover to unique sets of observations that measure such factors as wind velocity, surface temperature, and sea-surface height. Today, NOAA's Satellite Services collect, process, and use environmental satellite observations to develop weather, climate, and other environmental products and long-term recorded observations to benefit people in all sectors of society. NESDIS also provides long-term stewardship of environmental data, managing the world's largest collection of atmospheric, geophysical, and oceanographic data derived from both ground and space-based systems. Over the next decade, research satellites will demonstrate their capability to observe and measure tropospheric wind, precipitation type, and carbon. NOAA will assess these capabilities to determine whether they should be added to the growing number of operational satellite data product lines to further satisfy evolving requirements.

In cooperation with other key government and international partners, NOAA plans to build an environmental satellite remote-sensing program to support NOAA's mission, ensure continuity of measurements when appropriate, provide fiscally responsible estimates of the planned capability, and extend NOAA's current and projected capabilities to improve our nation's ability to save lives and property.

2.2 National Policy, Legislative Mandates, and Drivers

Policy, legislative regulations, and a variety of external drivers dictate NOAA's diverse mission goals—Climate, Ecosystems, Weather and Water, Commerce and Transportation, and Mission Support—to protect the environment and acquire the necessary measurements for environmental forecasts and modeling. Satellites and satellite services support all of NOAA's mission goals by providing specific environmental measurements to meet these requirements.

The priorities of this plan are based on the National Space Policy 2006 and other notable regulations. These directions and guidelines have influenced the NOAA Strategic Plan, the mission goal priorities, and the remote sensing requirements.

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U.S. Space Policy: There are four national objectives of the National Space Policy 2006 that guide NOAA's priorities and requirements for remote sensing:

- Increase the benefits of civil exploration, scientific discovery, and environmental activities.
- Enable a dynamic, globally competitive domestic commercial space sector in order to promote innovation, strengthen U.S. leadership, and protect national, homeland, and economic security.
- Enable a robust science and technology base supporting national security, homeland security, and civil space activities.
- Encourage international cooperation with foreign nations and/or consortia on space activities that are of mutual benefit and that further the peaceful exploration and use of space, as well as to advance national security and foreign-policy objectives.

In addition to the U.S. Space Policy, NOAA considered other key policy and legislative mandates when developing this plan. These additional directives are described in Appendix B.

2.3 Methodology

This assessment began by reviewing NOAA's requirements, professional studies, and recommendations from relevant scientific community documents. Current instrument performance was assessed to determine if the measurements satisfied the requirements listed in the Consolidated Observation Requirements List (CORL). The CORL is the single NOAA-wide operational observational requirements database.

Next, a three-day technical exchange working group was convened with invitees from across NOAA and key representatives from NASA. The working group explored the future of satellites as they relate to the NOAA mission in an effort to provide a better understanding of how satellites will acquire environmental information in the future. The second part of the workshop explored the capabilities and potential requirement candidates of future satellite instrument families.

Further analysis compared the findings to the current set of satellite requirements in the CORL, which has more than 800 mission-critical requirements listed. These requirements were grouped into 23 measurement areas and cross-referenced to their respective instrument suites with associated timelines to assess current mission sustainment. Detailed information on each of these 23 measurement areas can be found in Appendix E. As a result of this analysis, the continuity and capability gaps were identified. These measurement areas were further evaluated against today's satellite systems (including the Geostationary Operational Environmental Satellite-R series [GOES-R] series and the National Polar-orbiting Operational Environmental Satellite System [NPOESS]) to determine if the requirements were being met, predominantly met, or not met based on temporal, spatial, spectral, or orbit deficiencies (see Section 4 for results of the analysis). Finally, a long-term strategic satellite capability and budget-planning process will be used to institutionalize annual updates in concert with the Planning, Programming, Budget and Execution System (PPBES) planning cycle and evolve the NOAA architecture to be consistent with the Global Earth Observation-Integrated Data Environment (GEO-IDE.) The NOAA GEO-IDE is a "system of systems"—a framework that provides effective and efficient integration of NOAA's many quasi-independent systems that individually address diverse mandates in such area as resource management, weather forecasting, safe navigation, disaster response, and coastal mapping.

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NOAA developed the strategic satellite plan with the following objectives:

- Evaluate the feasibility of maintaining measurement and service continuity (consistent with user requirements) and continue ancillary functions, such as search and rescue, data collection systems, and emergency managers communications.
- Participate with the Department of Defense (DoD) and NASA on the NPOESS and follow-on polar-orbiting satellites consistent with the 1994 Presidential Decision Directive.
- Develop and maintain partnerships. The plan assumes a continued joint partnership with the European Space Agency (ESA)/European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) for the Meteorological Operational Satellite (MetOp), Centre National d'Etudes Spatiales (CNES) for Jason, research agencies (e.g., NASA) for research-to-operations transfers, and U.S. Group on Earth Observations (USGEO) for the Global Earth Observation System of Systems (GEOSS).
- Adhere to jointly defined standards and protocols, such as the GEO-IDE and Service-Oriented Architecture frameworks as prescribed by GEOSS.

NOAA developed the projected program (Section 4.3) with the following assumptions:

- Continue Geostationary and Polar-orbiting Satellite Missions
- Continue ancillary functions: search and rescue, data collection systems, and emergency managers communications
- Commit to Advance Sounder capability for GOES-T and beyond
- Commit to solar wind and coronagraph capabilities
- Participate with DoD and NASA on NPOESS and follow-on polar satellites consistent with the 1994 Presidential Decision Directive
- Continue the joint partnership with ESA/EUMETSAT: MetOp and Jason
- Ensure research-to-operations transition from partner agencies (e.g., NASA Operational Instrument Improvement Program [OIIP])
- Participate in GEOSS
- Centralize the CORL as the NOAA database for requirements management
- Develop an Integrated Ground System
- Adhere to jointly defined standards and protocols of the GEO-IDE and Service-Oriented Architecture frameworks as prescribed by GEOSS
- Begin New Start for Scatterometry mission
- Program for follow-on Altimetry mission
- Commit to VIIRS-like Imager upgrade for EUMETSAT
- Re-manifest Earth Radiation Budget instrument onto NPOESS C3 or other satellite
- Re-manifest Aerosol Polarimeter onto NPOESS or other satellite
- Re-manifest Ozone Profile instrument onto NPOESS or other satellite
- Re-manifest Solar Irradiation mission onto NPOESS C3 or other satellite

The planned and proposed Satellite Program costs include the following:

- Acquisition

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- Satellite Services
- An integrated ground system (up to the user's interface)
- Research-to-operations transitions
- Communication links and data relays
- Data buys for environmental measurements where it is cost-effective, such as Sea-viewing Wide Field of View Sensor (SeaWIFS), Orbview, IKONOS, Satellite Pour l'Observation de la Terre (SPOT), Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC), and RadarSat
- Support of the data archive and modification of the Comprehensive Large Array Data Stewardship System (CLASS)
- Modeling (e.g., Joint Center for Satellite Data Assimilation [JCSDA])—models used for transitioning science to operational products

This plan does not include the costs associated with model operation and development (e.g., the National Weather Service), indirect end-user product delivery (e.g., delivery of forecasts made using the satellite data), user equipment (e.g., user's interface), or satellite transmitters on in-situ measurement systems (ships, buoys, planes, etc.).

2.4 Recent Events

In addition, the analysis took note of significant events impacting satellite planning (e.g., Nunn-McCurdy, interagency assessments, Analysis of Alternatives [AoA], and the National Research Council's [NRC's] *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*) that shaped and influenced NOAA's environmental observations and satellite systems. Two of the events affected the polar-orbiting system, one affected the geostationary orbiting system, and one affected both systems.

Nunn-McCurdy: The NPOESS system was certified by the Congressionally-mandated Nunn-McCurdy Act on June 5, 2006. NPOESS is managed by the tri-agency Integrated Program Office (IPO) utilizing personnel from the Department of Commerce, DoD, and NASA, and was required to be re-certified by the Nunn-McCurdy process in accordance with U.S. law due to DoD cost overruns exceeding 25 percent. This certification placed a priority on the continuity of operational weather measurements at the expense of climate and space weather measurements. The climate sensors for ozone, aerosol, earth radiation budget, total solar irradiance, and altimetry were de-manifested from the NPOESS. The space weather sensors were reduced from a suite of six to a suite of three and remain on only one of the two remaining orbit planes.

Interagency Assessment: NOAA and NASA conducted a joint assessment to review and assess possible mitigation approaches to address the climate observation impacts based on the NPOESS Nunn-McCurdy certification. A cost study was initiated to examine options for re-manifesting sensors onto NPOESS, including costs for development and stewardship of climate data records. The cost to re-integrate de-manifested sensors onto spacecraft was included in the NPOESS budget. A parallel NASA cost-study of potential gap-filler missions was also undertaken. In addition, NOAA continues to work with the Office of Science and Technology Policy to determine a recommended path forward for the climate and space environment measurements.

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Analysis of Alternatives (AoA): Due to cost and risk challenges, the GOES-R program office decided to de-manifest the advanced sounding and coastal water imaging sensors (Summer 2006). As a result of this decision by NOAA, an AoA team studied and estimated the cost of the alternatives to meet the requirements originally satisfied by these instruments. The AoA determined an operational advanced sounder was needed to satisfy NOAA requirements and recommended a demonstration instrument. Upon proving the capability, the sounder instrument would be added as an operational instrument on the GOES-T satellite. The AoA team recommended a series of low Earth orbiting satellite sensors to address the coastal waters requirement.

NRC Decadal Survey: The final event to influence NOAA satellites was a report by the National Research Council Committee on Earth Science and Applications from Space. The committee's final report, "*Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond*" is hereafter called the Decadal Survey. The Decadal Survey represents the broad scientific community views of the most important measurements for the next decade. It also identifies important policy issues that must be addressed if the nation is to maintain and grow its scientific leadership role on space-based observations. The report directly addresses the loss to the nation due to NPOESS and GOES-R budget restructuring and re-scoping. It promotes cross-agency planning to avoid "observational capability gaps" and provides details on important benefits that could be accrued given appropriate resources. The Decadal Survey recommended NOAA operate ocean surface vector wind, Global Positioning Satellite (GPS) Radio Occultation (GPSRO), and solar/Earth radiation characteristics missions. This plan acknowledges the report findings and has recommended feasibility studies, including benefit analysis to determine the appropriate sensing platforms.

2.5 Science Directions

Science forms the foundation of the NOAA satellite mission requirements and is central to understanding environmental interrelationships and reducing the risk of severe consequences. With technological breakthroughs, more information can and will be acquired from space-based platforms. As part of the strategic planning effort, the relevant science issues were reviewed and the areas for further exploration into the feasibility of meeting observational requirements on future satellite platforms were identified. Two examples are bathymetry and soil moisture.

- Bathymetry (high-resolution) is needed to improve the calculation of the inundation line—the inland limit of wetting (e.g., maximum Tsunami penetration) measuring horizontally from the mean sea level line—in order to increase the impact and accuracy in tsunami predictions and support safe maritime navigation.
- Soil moisture (depth) is needed to reduce uncertainties in predicting floods and improve water-runoff forecasts and reservoir management. NASA is exploring a research microwave radiometer. It is proposed that NOAA evaluate the feasibility of this instrument for its operations.

Advances in satellite technology, research, and applications help provide improved satellite systems to better support government, international, and academic partners. For example, NOAA collaborates with NASA scientists to explore solutions to meet requirements. NOAA science and research also benefits from established collaborations with its Cooperative Institutes. These academic and research institutions provide analyses relevant to NOAA's mission and perform trade studies critical to planning the next generation of environmental satellites. For example,

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one collaborative trade study demonstrated that the spectral response function of the GOES-R Advanced Baseline Imager (ABI) channels could be slightly modified to detect volcanic plumes of sulfur dioxide (SO_2) gas while still satisfying water vapor mapping requirements. This change improved ABI's ability to monitor climate and support forecasting of aviation hazards with minimal cost implications.

Additional technology advancement cases include, but are not limited to, the following:

- Applied research in remote sensing of snowfall using microwave and sub-millimeter wavelength radiometers from a geostationary platform, which would improve forecasts of precipitation type and amount.
- Synthetic Aperture Radar observations of polar ice surface elevation, ice thickness and extent, and all-weather day/night imagery monitor ice surface deformation and determine inundation extent. Ocean SAR retrievals include winds, features, and ship detection. These measurements could increase the forecast skill for polar and Arctic maritime passage, as well as monitor climate trends in rapidly changing conditions of ice cover.

Current research is developing new methods to integrate satellite observations with new modeling capabilities and analysis tools that better represent the physical processes of the Earth system. This will lead to improved ways of representing these processes in forecast models and ultimately lead to improved weather forecasts.

The Satellite Strategic Plan recognizes the need to meet NOAA's operational and regulatory needs while maintaining a commitment to science. Applied research on satellite product development makes operational satellite data more valuable to our user community. This responsibility includes the transition from research-to-operations.

2.6 Research-to-Operations Transition Opportunities

Effective transition of research-to-operations provides an opportunity for improved satellite capabilities and ground service equipment with the potential for a significant return on investment. To fully capitalize on research-to-operations transition opportunities and to implement nationally integrated Earth observation investment priorities, NOAA plans to leverage and support joint NASA-NOAA systems focused on developing new sensors for operational services through an OIIP. The OIIP builds on the ongoing NOAA-NASA Research-to-Operations Joint Working Group and is expected to accelerate the transition to operations timeline while reducing the costs to acquire and launch new operational satellite sensors.

Near-term efforts will emphasize joint planning for innovative and collaborative NOAA-NASA systems focused on new sensors for operations. NASA and NOAA will work together to select missions and consider implementation of the proposed research-to-operations transition process. This process will allow NOAA to identify high-priority instrument requirements for transition and allows NASA to develop demonstration sensors to be flown on NASA, NOAA, or international spacecraft (flights of opportunity). NASA's acquisition strategy will include contract options to procure follow-on sensors. NOAA would assume responsibility for funding subsequent instrument builds within acquisition processes.

This satellite plan looks to OIIP as the method to potentially transition NASA's Aerosol/Clouds/Ecosystems Mission (ACE); Deformation, Ecosystem Structure, and Dynamics of Ice (DESDynI); Soil Moisture Active Passive (SMAP); Climate Absolute Radiance and

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Refractivity Observatory (CLARREO); Orbiting Carbon Observatory (OCO); Global Precipitation Measurements (GPM); and dual-frequency lidar research missions to NOAA operational missions.

2.7 Partnerships

NOAA works closely with interagency and international partners to improve U.S. and global environmental understanding. These partnerships provide mutual benefits and share costs for data collecting, modeling, and distribution.

NOAA's U.S. partners include NASA and DoD. The GOES system has a joint program office—NASA develops and launches the satellites needed to meet NOAA's requirements. NOAA provides oversight, resources, and ground systems. After post-launch tests, the system is operated by NOAA. A tri-agency model (DoD, NOAA, and NASA) is used for the NPOESS acquisition.

International partnerships include ESA/EUMETSAT, CNES, Japan Aerospace EXploration Agency (JAXA), and Comisión Nacional de Activades Espaciales (South America).

NOAA and EUMETSAT work together to support the Initial Joint Polar System (IJPS) and NOAA is helping EUMETSAT develop the MetOp satellite. The MetOp satellite provides flight opportunities for NOAA sensors and fills the third critical polar orbital plane (mid-morning) in NOAA's three satellite polar operational constellation. Both organizations gather data to supplement global forecasting models while supporting each country's meteorological and climate missions.

NOAA also supports CNES with the Search and Rescue Satellite (SARSAT) and Advanced Data Collection System (ADCS) (also known as Argos) sensors. Each sensor flies on both geostationary and polar satellites and globally supports rescue and data collection efforts. Other partnerships include JAXA and EUMETSAT, where NOAA provides a backup capability in the event of the loss of system availability.

In addition, NOAA has multiple "data buys" from Canada and Taiwan. These data buys provide ice, moisture, and temperature data to the National Ice Center and the National Centers for Environmental Prediction (NCEP).

Finally, NOAA's international partnerships support mutually beneficial data collection, purchase, and exchange. In addition, cost and risk sharing—through formal and informal agreements (e.g., IJPS and MetOp), GEOSS, and other important observing groups and efforts—will further integrate and enhance NOAA's observing systems, data, and quality control.

2.8 NOAA Satellite Ground System—Integration

To carry out its mission, NOAA must understand and address the complexity of many environmental problems and answer questions addressing contemporary societal needs. To succeed, NOAA has established a well-ordered, standards-based data and information infrastructure that allows users to easily locate, acquire, integrate, and utilize NOAA data and information (see Figure 3). NOAA must integrate data requirements from across the agency and exchange data with partners in the national/international observing systems (such as USGEO and the international GEOSS). NOAA satellite data is acquired and processed through NOAA satellite operations using cross-cutting services that provide the flexibility to service all satellites with minimal dedicated system equipment. This service will become a subset of the NOAA service-oriented architecture, which is a subset of the GEO-IDE.

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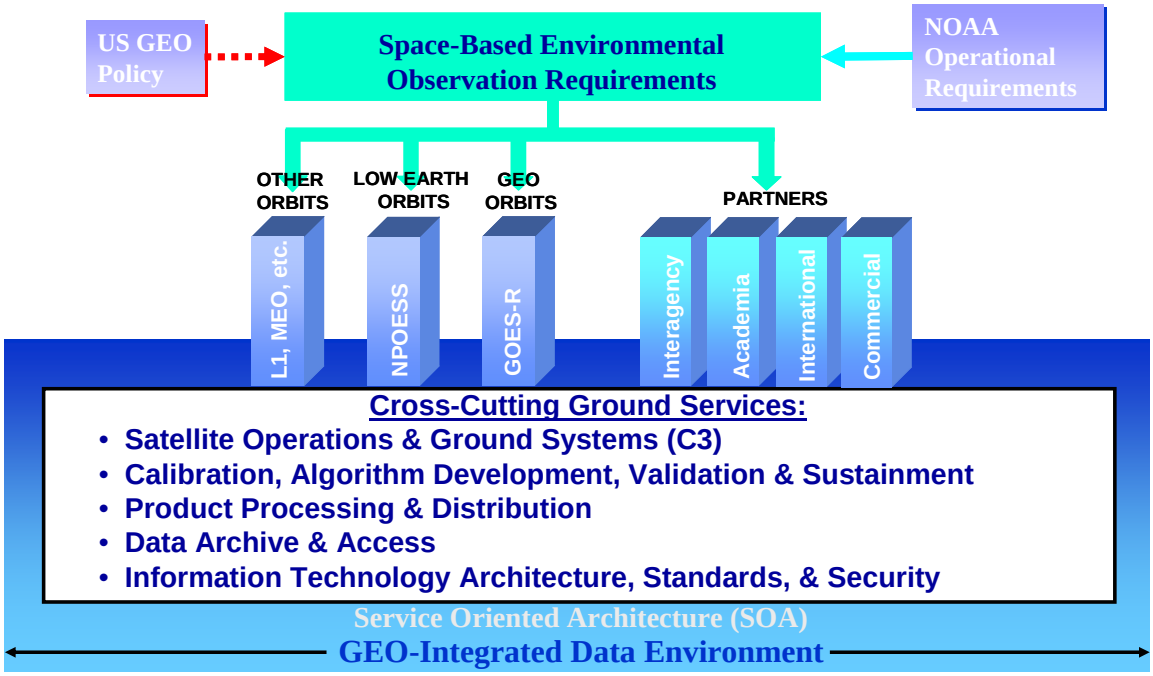

Figure 3: A Framework to Effectively Integrate NOAA's Operational Satellite Support

A service-oriented architecture is a systems design that uses loosely coupled connections among independent programs to create scalable, extensible, interoperable, reliable, and secure systems. Service-oriented architectures have solved interoperability problems, including integrating systems developed in various programming languages that run on different computing environments and were developed by autonomous groups at different times. These architectures make it practical to adapt and connect existing systems quickly for accomplishing new tasks and to benefit from highly evolved and still useful "legacy" applications. These systems also allow users access to the information they are looking for in a format that meets their needs and can be served to the users via straightforward data and product transactions.

NOAA will continue to participate in the GEOSS and will comply with and implement program standards and protocols as specified in the GEO-IDE. The NOAA GEO-IDE is a "system of systems"—a framework that provides effective and efficient integration of NOAA's many quasi-independent systems (platforms) that individually address diverse mandates, resource management, weather forecasting, safe navigation, disaster response, and coastal mapping. NOAA will also continue to evolve a service-oriented architecture framework as prescribed by GEOSS. As GEOSS matures, the GEO-IDE will link to the global network, allowing data-sharing, global modeling, and combined programs. To implement this service-oriented architecture, the following cross-cutting ground services will be provided:

- Satellite operations and ground systems
- Calibration, algorithm development, validation, and sustainment
- Product processing and distribution
- Data archive and access
- Information technology architecture, standards, and security

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Satellite operations and ground systems include command and control of the satellites, tracking the satellites, acquisition of data, and mission disposal. Ground systems—both hardware and software—are required to carry out these functions.

Calibration, algorithm development, validation, and sustainment include a number of functions. The satellites transmit raw data that requires calibration prior to distribution. This includes analysis of the pre-launch calibration and the post-launch instrument performance, checkout, and the development of on-orbit calibration procedures and monitoring. Sensor validation may be done pre-flight using various references—such as the moon's radiance—or through overlapping missions that allow lengthy sensor intercalibration. Comparison with high-spectral resolution sensors, such as global positioning satellite radio occultation (GPS-RO) is also used to validate broadband spectral sensors. Most satellite data is then processed through science algorithms to derive user-defined products. NOAA scientists lead efforts to develop, test, and validate these science algorithms. Validation of algorithm products is often achieved through comparison with ground-based, aircraft, or balloon-launched or in-situ observations. Sustained monitoring of satellite observations and derived products is required to provide the time trends to define instrument drift needed by calibration teams.

Product processing and distribution includes real-time product generation and the distribution of products to users. Data from polar, geostationary, research and international satellites is processed as soon as it arrives at NOAA's processing center. The satellite data generates approximately 450 individual products such as cloud imagery, sea surface temperature, etc. Due to the time perishable nature of the environmental products, the environmental information is distributed as soon after their generation as possible via NOAA satellite broadcast and internet capability like NOAA Port. In addition, NOAA is developing a new program called GeoNetCast to provide improved worldwide dissemination of satellite data. This data will provide more accurate forecasts in both developed and under-developed nations.

Data archive and access include NOAA's establishment of four data centers that support the archive and distribution of NOAA data and products. These NOAA National Data Centers—the National Climatic Data Center (NCDC), the National Oceanographic Data Center (NODC), the National Geophysical Data Center (NGDC), and the National Coastal Data Development Center (NCDDC; a component of NODC)—preserve observation records encompassing manual and machine data collected in analog and digital form over the past 150 years. NOAA must ensure a plan for long-term storage of relevant calibration, characterization, and validation data. The archive function is an active process that ensures continuing and growing utility as it provides for continual growth, actively maintaining and understanding the data and information, and providing discovery services and access to the data collection. Collected data is useless if it cannot be retrieved, analyzed, and understood, so it is necessary to have both an active program of technology refresh (replacing aged computers and storage devices) and a robust program of scientific stewardship. Each data center has an extensive group of users, including private industry; educational institutions; federal, state, local, and foreign governments, and the general public.

Information technology architecture, infrastructure, standards, and security are an important component to system integration. They include the following functionalities:

- Telecommunications and networking—All communications requirements from "photons to products", that is from the transmission of raw data collected by satellite sensors to the final products prepared and distributed to the end user or archival facility.

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- Compliance with standards and protocols (such as GEOSS and GEO-IDE)—addresses common format standards and means of data and metadata access, interoperability, processing, dissemination, and archiving; to the maximum extent possible, compliance will be based on non-proprietary standards such as those of the International Organization for Standardizations (ISO).
- Compliance data security requirements—Defined as the process of establishing and maintaining a framework and supporting management structure and processes to provide assurance that information security strategies are aligned with and support business objectives, are consistent with applicable laws and regulations through adherence to policies and internal controls, and provide assignment of responsibility, all in an effort to manage risk.

As NOAA moves toward the goal of integrated data management, the challenges will be to continue to identify goals and activities, measure progress, work towards measurable outcomes and deliverables, communicate accomplishments, listen to critical feedback, learn from successes and failures, and continually reinvent processes, in light of constrained resources. This is an important factor for the success of this plan.

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3 Findings and Analysis

3.1 Satellite Orbits and Continuity

NOAA currently acquires environmental observations and achieves continuity of operations through a constellation of NOAA and other agency satellites. The backbone of the NOAA weather satellites includes the GOES and Polar-orbiting Operational Environmental System (POES) satellites (Figure 4). Together, these two systems provide the U.S. civil space-based component of an operational global environmental monitoring system. Throughout the strategic satellite plan, NOAA is committed to continuing the GOES and POES systems, as well as NOAA's partnerships with other agencies (NASA, DoD, and NOAA's foreign partnerships with EUMETSAT and CNES).

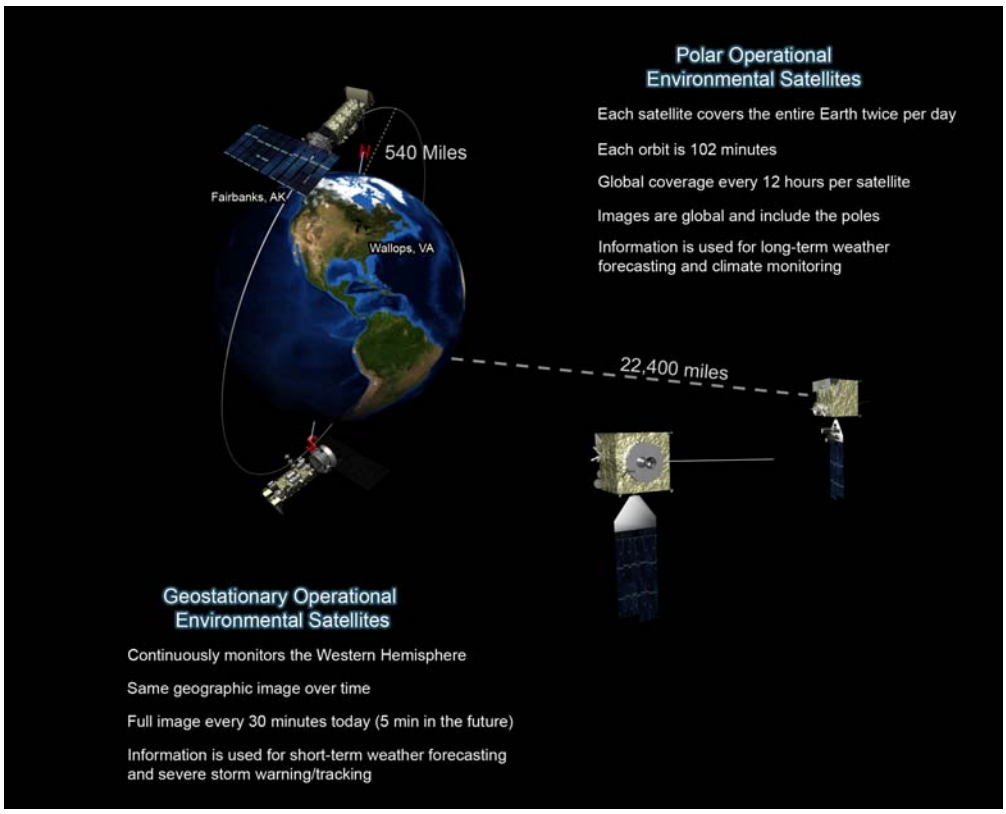

Figure 4. Geostationary and Polar Environmental Satellites

NOAA operates a system of environmental satellites in geostationary orbits, providing continuous monitoring from the same longitude and from two distinct orbital planes to provide coverage across the eastern United States, most of the Atlantic Ocean, the western United States, and Pacific Ocean basin. In addition, an on-orbit spare is required to allow a rapid recovery from a failure of either of the geostationary operational satellites. Launch scheduling is based on the contractual mission design life of each satellite. GOES satellites provide critical atmospheric, oceanic, and climatic data images of the entire United States every 15 minutes supporting weather forecasting, climatologic analysis and prediction, ecosystems management, and safe and efficient public and private transportation. The GOES satellites also provide a platform for solar and space images/observations, data collection, search and rescue, and other environmental observations.

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Currently, the GOES System consists of three series of satellites. The GOES-I Series (8-12) is the current operational series. The GOES-N Series (13-14-15) launched GOES 13 in 2005, and GOES 14 and 15 are scheduled for 2009 and 2011 respectively. The GOES-R Series is a major system upgrade with initial launch capability in 2014. GOES has been and will continue to be collaboratively developed and acquired by NOAA and NASA. The acquisition of the end-to-end GOES system includes spacecraft, sensors, launch services, and ground system elements consisting of mission management, product generation, product distribution, archive and access interface, and user interface.

NOAA's POES and the NPOESS spacecraft orbit north to south across the poles in three sun-synchronous orbital planes to provide comprehensive global coverage. POES is NOAA's current operational polar system, which has one satellite remaining to be launched in 2009. The POES System—initially designed and launched in the mid-1970s—is the follow-on to the family of polar satellites that have provided global coverage since 1960. The POES System is also providing sensors to EUMETSAT under two international agreements for flight on three of their MetOp satellites, which initially launched its first satellite in 2006 and has a second launch scheduled for 2015. Mandated by Presidential Decision Directive to converge and replace the POES and the DoD's Defense Meteorological Satellite Program (DMSP), NPOESS is a major polar-orbiting upgrade with an initial launch in 2013.

GOES and POES are operated to provide critical atmospheric, oceanic, climatic, solar, and space data images to protect life and property across the United States. The data from each orbit complements the other through inter-calibration/validation, leading to improved measurements and product accuracy. In addition, both types of satellites provide platforms for solar observations, data collection, search and rescue, and other environmental observations. GOES and POES satellite continuity missions are shown in Figure 5 and Figure 6.

Continuity of NOAA's operational satellite mission is complemented by interagency and international measurements. In fact, NOAA uses many of those measurements for operational purposes. Appendix D summarizes some of the NASA measurements from research satellites that are used by NOAA operations. These external data sources are serving a growing community of users. As a result of the research-to-operations transition successes, there is an increased dependency on non-NOAA observations. This creates challenges when mission users are unexpectedly denied measurements due to external funding decisions or research system limitations. For instance, while the NASA Tropical Rainfall Measuring Mission (TRMM) satellite has provided important research and operational data for more than a decade, it was only designed and funded for six years. Operational users expressed concern when NASA recently decided to close down the operations of the TRMM research satellite and begin a follow-on system. This concern led to a review of TRMM operations. NASA decided to continue operating the research satellite to provide continuous data to NOAA and other users. Continuing the TRMM had a fiscal impact because additional NOAA funding was required that was not planned or programmed. This example highlights the need to ensure that critical measurements from any source are included in long-term planning and prioritized by impact on mission success.

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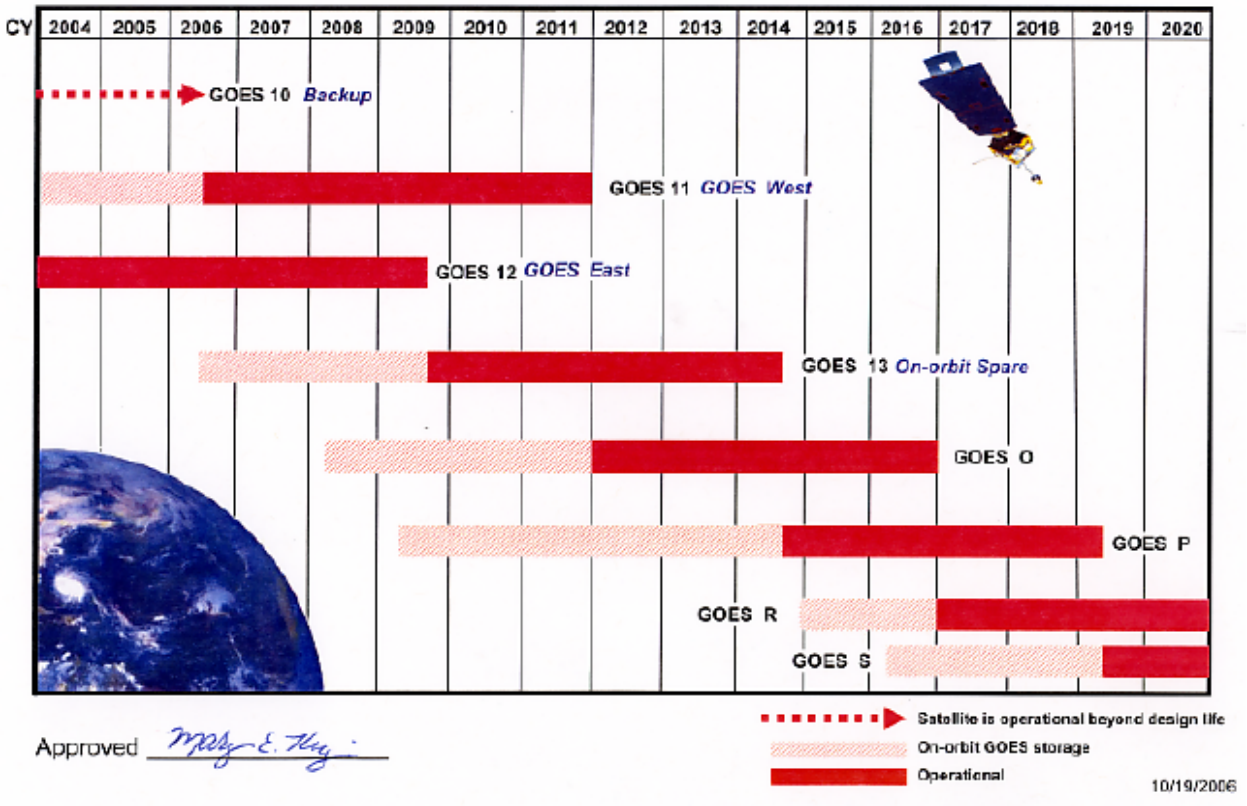

Figure 5: Continuity of NOAA Geostationary Systems

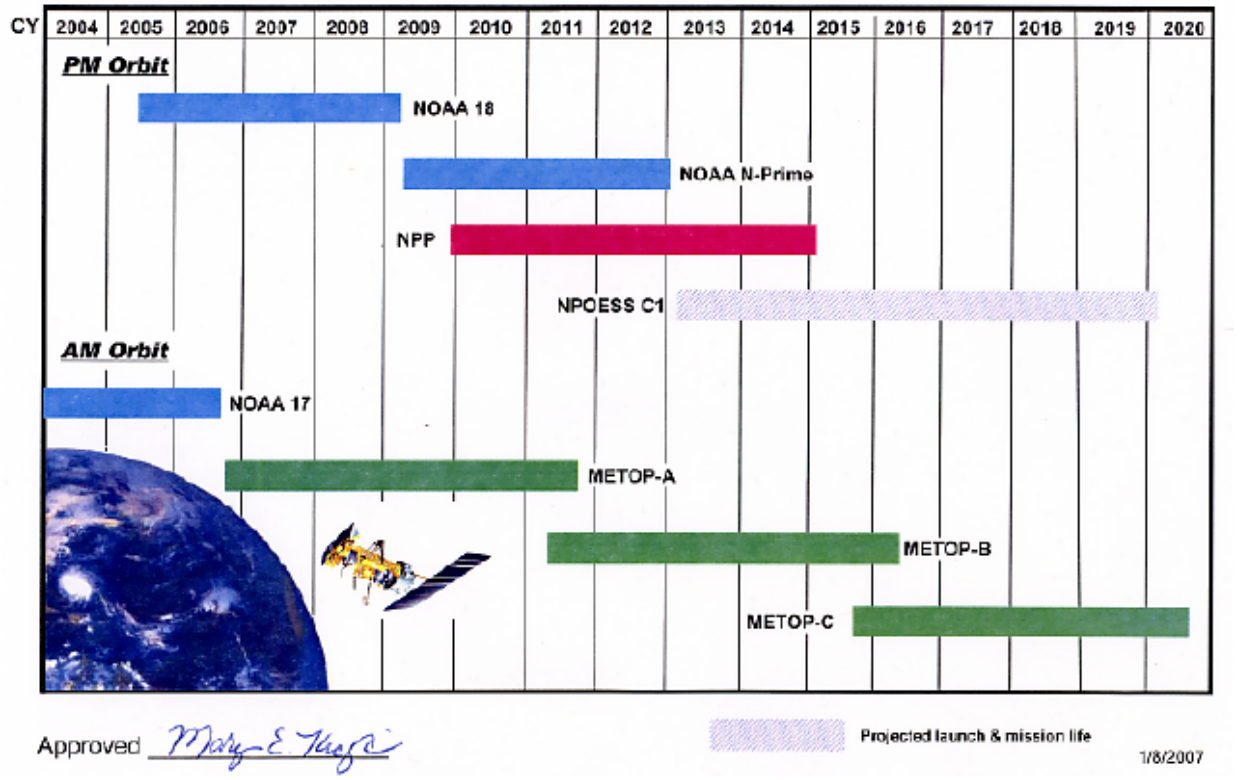

Figure 6: Continuity of NOAA Polar-Orbiting Systems

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For the potential optimization of capability efficiencies, additional orbits under review for future satellite missions include the mid-Earth orbit (MEO), Molniya, and L1 libration point. MEOs are higher than low-Earth orbits and lower than geostationary orbits. Molniya orbits are highly elliptical and provide the ability to dwell over polar regions for long periods. A satellite orbiting the L1 libration point will maintain a fixed position between the Sun and the Earth and provide early measurements of the solar particulate output to help monitor Earth's space environment. Currently, NOAA uses data from the NASA's Advanced Composition Explorer (ACE) mission in L1 orbit for solar winds and imaging the Sun. Although NOAA does not plan to launch these additional orbits in the next decade, they will be analyzed for operational need in the decades that follow.

3.2 Measurement Areas

The team analyzed the more than 800 mission-critical requirements identified within the CORL and grouped them into 23 measurement areas. To assess current mission sustainment, these measurement areas were cross-referenced to their respective instrument suites with their associated timelines. As a result of this analysis, the planned continuity and capability gaps were identified. Each of the measurement areas are defined below.

1. *Imagery/Radiometry Visible/InfraRed (VIS/IR)*: Provides visual imagery of cloud cover, cloud properties, surface delineation, vegetation index, and clear sky sea surface temperature.
2. *Imagery/Radiometry Microwave (MW)*: Provides time-series imagery of column-integrated amount of water vapor and liquid water.
3. *Atmospheric Temperature Profiles*: Measures the temperature at all altitudes in the atmosphere.
4. *Atmospheric Moisture Profiles*: Measures the water vapor amounts at all altitudes in the atmosphere.
5. *Precipitation Type*: Determines types of precipitation, including rain, drizzle, freezing rain, freezing drizzle, hail, or sleet.
6. *Lightning*: Detects and maps the distribution and variability of total lightning discharges (cloud-to-cloud, intra-cloud, and cloud-to-ground lightning) during both day and night.
7. *Soil Moisture*: Determines water content in the soil.
8. *Ocean Surface Vector Winds*: Provides near–real-time measurements of ocean surface wind speed and direction.
9. *Sea Surface Height*: Measures the height (or "relief") of the sea surface caused by both gravity and the active ocean circulation.
10. *Ocean Color*: Measures ocean color. Phytoplankton contains chlorophyll, which absorbs red and blue light and reflects green light. Particles can reflect and absorb light, which reduces the clarity (light transmission) of the water. Dissolved organic matter strongly absorbs blue light, and its presence can interfere with measurements of chlorophyll.
11. *Coastal Water/Ocean Habitats*: Provides high-resolution imagery for base maps and wetland guidance maps allowing users to discern land use or land cover.
12. *Bathymetry*: Measures water depth; ocean bottom topography.
13. *Earth Radiation Budget*: Measures balance between incoming energy from the sun and the outgoing long wave (thermal) and reflected short wave energy from the Earth.
14. *Aerosols*: Measures dispersion of solid and liquid particles suspended in the atmosphere.

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15. *Ozone Profile*: Provides measurements of distinct layers in the atmosphere and troposphere where ozone either increases or decreases with height.
16. *Solar Irradiance*: Measures of the rate of solar energy arriving at the Earth's surface from the Sun's direct beam, on a plane perpendicular to the beam.
17. *Carbon*: Measures carbon dioxide (CO_2), carbon monoxide (CO), methane, carbonyl sulfide, etc., data to improve our understanding of the natural processes and human activities that regulate the abundance and distribution of this important greenhouse gas.
18. *Snow Depth*: Measures depth of snow between the vertical interval between the top surface of a snow layer and the ground beneath.
19. *Ice Thickness*: Determines ice surface elevation and ice thickness.
20. *Tropospheric Winds*: Determines atmospheric wind speed and direction data above cloud/surface (clear sky).
21. *Radio Occultation*: Provides indirect measurement of temperature, pressure, and water vapor in the stratosphere and the troposphere.
22. *Space Environment*: Determines the plasma, energetic particles, and electric fields (LEO) and magnetic (GEO) conditions in the magnetosphere and the ionosphere.
23. *Solar Measurements*: Determines the solar wind plasma, energetic plasma, and magnetic field conditions in a solar wind upstream from Earth and determines the solar x-ray and Extreme Ultra Violet (EUV) flux, the occurrence of coronal mass ejection (CME), and the location of active regions, flares and the coronal hole of the sun.

These measurement areas were further evaluated against today's satellite program (including GOES-R series and NPOESS) to determine whether the requirements were met, predominantly met, or not met based on temporal, spatial, spectral, or orbit deficiencies.

Table 1 references each goal with requirements in each measurement area as contained in the CORL. The table also contains a comparison of NOAA requirements with documented environmental observation recommendations from the community of users. The strong similarity in NOAA requirements and external recommendations indicate NOAA is planning to serve its user constituency effectively. Atmospheric Moisture Profiles, Coastal Waters/Habitat, Bathymetry, and Precipitation Type were identified and documented within NOAA but not in the other external documents listed in Table 1. It should be noted that the bulk of NOAA's critical observational requirements are associated with the Imagery/Radiometry, Atmospheric Temperature, and Moisture Profiles measurement areas. NOAA used the measurement areas as a way to analyze whether requested measurements capabilities will be satisfied.

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Measurement Area	Mission Goals Supported				External Community Recommendations				
	WW	CLT	ECO	C&T	CEOS	WMO	GCOS	Decadal Survey Ops	Decadal Survey Mission
Imagery (VIS/IR)	X	X	X	X	Land, Water, Ocean, Cryosphere	X	X	Surface/ice deformation, natural hazards, vegetation structure	Deformation, Ecosystem Structure and Dynamics of Ice (DESDynI*)
								Land surface composition and mineral character	Hyperspectral IR Imager (HyspIRI)
Imagery (MW)	X	X	X	X	Land, Water, Ocean, Cryosphere	X	X	Ocean, Lake, and River water levels	Surface Water and Ocean Topography (SWOT)
Atmospheric Temperature Profiles	X	X	X	X	Atmos Chem, Land, Water, Ocean	X	X	High Frequency Temperature/Moisture Sounding	Precipitation and All-Weather Temperature and Humidity (PATH)
Atmospheric Moisture Profiles	X	X			Atmos Chem, Land, Water, Ocean	X	X	High Frequency Temperature/Moisture Sounding	Precipitation and All-Weather Temperature and Humidity (PATH)
Precipitation Type	X	X	X	X	Water	X	X		
Lightning	X			X	Water	X	X		
Soil Moisture	X	X	X		Water	X	X	Soil Moisture Active Passive	Soil Moisture Active Passive (SMAP*)
Ocean Surface Vector Winds	X	X	X	X	Water, Ocean	X	X	Sea Surface Wind	Extended Ocean Vector Wind Mission (XOVWM**)
Sea Surface Height	X	X	X	X	Water	X	X		
Ocean Color	X	X	X		Water, Coastal			Air quality and coastal ocean color, pollution	Geostationary Coastal and Air Pollution Events Mission (GEOCAPE)
Coastal Waters/Ocean Habitats	X	X	X	X	Coastal				
Bathymetry	X	X	X	X					

Table 1. Key for Measurement Areas and Goals

Measurement Area	Mission Goals Supported				External Community Recommendations				
	WW	CLT	ECO	C&T	CEOS	WMO	GCOS	Decadal Survey Ops	Decadal Survey Mission
Earth Radiation Budget	X	X	X	X	Atmos Chem	X	X	Sun, Earth Radiation Characteristics	Climate Absolute Radiance and Refractivity Observatory (CLARREO)
Aerosols	X	X	X	X	Atmos Chem, Geohazards	X	X	Aerosol/cloud profiles, climate and ocean color	Aerosol/Clouds/Ecosystems Mission (ACE)
Ozone Profiles	X	X			Atmos, Chem		X	Ozone and air quality (large scale)	Global Atmospheric Composition Mission (GACM)
Solar Irradiance	X	X			Atmos, Chem		X	Climate Absolute Radiance and Refractivity Observatory (CLARREO)	Climate Absolute Radiance and Refractivity Observatory (CLARREO)
Carbon	X	X	X		Carbon		X	Day/Night all-latitude, all-season CO2	Active sensing of CO2 Emissions over Nights/Days/Seasons (ASCENDS)
Snow Depth	X			X	Cryosphere		X	Snow accumulation for fresh water availability	Snow and Cold Land Processes (SCLP)
Ice Thickness	X	X	X	X	Cryosphere		X	Ice Sheet Height	ICEsat-II
Tropospheric Winds	X	X	X	X		X	X	Tropospheric (lower atmosphere) winds	3D Tropospheric Winds (3D-Winds)
Radio Occultation	X	X	X	X		X		Temperature, moisture and electron density profiles	Operational Global Positioning system Radio Occultation (GPSRO)
Space Environment	X			X		X	X	Ionospheric Variability	Ionospheric Mapper
Solar Measurements	X			X		X	X	Sun, Earth Radiation Characteristics, In-situ solar wind, coronal mass ejection, imaging	Climate Absolute Radiance and Refractivity Observatory (CLARREO), and STEREO

Table 1. Concluded

The analysis indicated met, predominantly met and unmet requirements, as follows:

Met Requirements—Satellite observation data meets or will meet spatial, spectral, orbital plane definition, and/or temporal resolution requirement attributes for given data record(s) in NOAA polar and geostationary orbits.

- *Lightning*: A new capability to meet user's requirements will be added as the Geostationary Lightning Mapper (GLM) on the GOES-R satellite, launch 2014.

Predominantly Met Requirements—Satellite observation data meets some spatial, spectral, orbital plane definition, and/or temporal resolution requirement attributes for given data record(s) in NOAA polar and geostationary orbits.

- *Imagery/Radiometry (Visible/Infrared [VIS/IR] and Microwave [MW])*: Future satellite imaging systems require the spatial and temporal resolution appropriate to the observed phenomena. Currently, the GOES satellites are meeting historical geostationary requirements. However, the planned GOES-R advanced imager will have the spatial and spectral bands relevant for the depiction of rapidly developing small-scale weather events. For polar satellites, the VIS/IR and MW imagery satisfies the long-range forecasting requirements in two of the three polar orbits. Due to the removal of a third satellite orbit for NPOESS (Nunn-McCurdy, 2006), DoD and EUMETSAT will provide measurements in the third polar-orbit crucial for the 4-hour refresh time requirements; however, these measurements will not meet the spatial or spectral requirements.
- *Atmospheric Temperature Profiles and Atmospheric Moisture Profiles*: The recently launched (2006) GOES-N/O/P sounders provide frequent atmospheric temperature and humidity soundings for improved weather forecasting and now-casting. However, the derived product images that will be provided by the GOES-R Advanced Baseline Imager (ABI) will only meet the temporal sampling requirements. The vertical profiling requirements needed to define boundary layer structures will not be met. The POES satellites are meeting historical requirements from polar orbit. NPOESS sounding technologies will satisfy a more stringent set of validated requirements for vertical profiles.
- *Ocean Surface Vector Winds*: Near-real time satellite ocean surface observations of wind speed and direction support operational marine weather warnings, analysis, and forecasts. These wind speed measurements have a long heritage using passive microwave measurements from the Defense Meteorological Satellite Program's Special Sensor Microwave Imagery Suite. Upon the end-of-life of a NASA research satellite Quick Scatterometer (QuikSCAT) with the SeaWinds instrument, EUMETSAT will provide scatterometry measurements from the Meteorological Operational (MetOp) Advanced Scatterometer (ASCAT) instrument, but at reduced spatial resolution and coverage.
- *Ocean Color*: Validated open ocean chlorophyll concentration requirements will be satisfied with the Visible Infrared Imager Radiometer Suite (VIIRS) on the NPOESS satellite, to be launched in 2013.
- *Space Environment*: Improved space environment measurements to meet user's requirements will be added as the Space Environmental In-Situ Suite (SEISS) on the GOES-R satellite, launch 2014. Additional measurements are taken by the Space Environmental Monitor (SEM) on the POES and NPOESS satellites. Geosynchronous measurement requirements are met, polar measurements are partially met, and solar wind and coronal mass ejection (CME)

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measurements are unmet. The MetOp SEM will provide space weather sensors similar to those on NOAA POES.

Unmet Requirements—An "Unmet" requirement indicates satellite observation data do(es) not meet spatial, spectral, orbital plane definition, and/or temporal resolution requirement attributes for given data record(s). It also encompasses those measurement requirements that are not currently operational without planned or approved acquisitions within the decade for a new capability.

- Significant enhancement opportunity areas (requirements not in priority order) that would improve NOAA's capability, but are currently unmet are:
  - Aerosols polarimetry
  - Carbon
  - Earth radiation budget
  - Precipitation type
  - Snow depth
  - Solar measurements
  - Coronal mass ejection
  - Albedo
  - Coastal waters/habitat
  - Ice thickness
  - Radio occultation
  - Soil moisture
  - Tropospheric winds
  - Bathymetry
  - Dissolved organic content of seawater
  - Ozone profiles
  - Sea surface height
  - Solar irradiance
  - Solar winds
- Five of these requirements are affected by the five de-manifested climate sensors (Nunn-McCurdy, 2006)
  - Aerosol polarimeter
  - Altimeter (Sea surface height)
  - Earth radiation budget
  - Ozone mapping and profiler suite limb
  - Total solar irradiance sensor

Overall, NOAA satisfies the majority of the current environmental requirements for Earth observation using satellites and other platforms. However, as requirements for Earth observation continue to grow, new sensor technology advancements are needed. This plan supports efforts to ensure cost-effective measurements are taken from satellites to meet new requirements. Table 2 illustrates the overall results, when considering the NOAA satellite systems in conjunction with complementary research and international data as a whole, of the 23 measurement areas and identifies the associated gaps, impacts, risks, and required decisions.

The associated gaps (partially met and unmet requirements) are further broken down into two categories: continuity and/or capability. Continuity gaps represent significant breaks in service of ongoing satellite observation measurements, and capability gaps represent observation requirements not fully met by available or planned satellite measurements.

The assessment assumes that instruments under development will perform as designed. As the programs develop, the final capabilities will be reassessed.

For this initial plan, a subjective risk assessment was completed; for subsequent plans, a more rigorous analysis will be performed. The risk of each gap indicates the anticipated impact and the most likely event of disruption to forecast skills and analysis and reflects the user communities' dependency on the measurement. (Probability analysis will be accomplished during feasibility assessment). The risks are defined as follows:

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High = High impact to forecast skill, analysis, or outcome with urgency to mitigate given projected gaps.

Moderate = High impact with minimal urgency or moderate impact with urgency to mitigate given projected gaps.

Low = Moderate/Low impact with minimal urgency to mitigate given projected gaps.

For each risk, quantifiable decision analyses are required in the near-term to mitigate or accept measurement shortfalls in environmental satellite observational capability.

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Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Imagery/Radiometry (VIS/IR)						Mid AM Polar Orbit, MetOp flies AVHRR (current imager) instead of VIIRS (planned imager)	• Improved ability to characterize snow packs, inc. snow water equivalent, snow depth; less accurate water runoff forecasts and reservoir capacity • Less accurate atmospheric column water, cloud liquid water, etc.; Increased NWP forecast skill • Upgraded weather forecasts and precipitation type identification, decreased forecast skill • Discontinuous satellite data measurements; decreased climate trend identification and accuracy	Low	EUMETSAT decision to upgrade to VIIRS-like instrument
Imagery/Radiometry (MW)						Mid AM Polar Orbit, MetOp has no MIS (microwave imager)		Low	No plan to close gap
Atmospheric Temp Profile						GOES & GOES-R have partial profiling capability	High-frequency temperature soundings improve mesoscale weather predictions	Low	Procure GOES T&U with new advanced sounder
Atmospheric Moist Profile						GOES & GOES-R have partial profiling capability	High-frequency moisture soundings improve mesoscale weather predictions	Low	Procure GOES T&U with new advanced sounder
Lightning						New start and operational in 2016	• Severe Weather indicator (cloud-to-cloud and intracloud lightning strikes) • Capability to continuously count and map lightning discharges during both day and night. • Ability to measure Tropical Storm intensity *Enhances current non-satellite ground systems	NA	Award post PDR GOES-R contract for development
Soil Moisture						DMSP SSMIS & NPOESS MIS have partial capability	Improvement to water, energy, and carbon management efficiencies • increased uncertainty in Flood prediction • Increased ability to assess ground moisture/saturation state • Improved irrigation plans	Moderate	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Ocean Surface Vector Winds						ASCAT (EUMETSAT Scatterometry) & MIS (NPOESS) partial capability, require QuikSCAT follow-on	• Upgraded hurricane model initial analysis leading to Increased intensity and forecast accuracy • Upgrades mesoscale model initial analysis; Increases forecast skill	Moderate	New Start Program for Scatterometry

Table 2. Measurement Areas Gap Analysis

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Sea Surface Height						Jason 1/OSTM-need continuation	• Ability to provide accurate ocean specification for numerical ocean models, Increased ocean prediction accuracy, and ocean circulation models • Upgraded capacity for predicting hurricane intensity/ocean heat potential; increased hurricane intensity and forecast accuracy • Continued sea level/height satellite record; climate trend identification and accuracy	High	Follow-On Program for Altimetry
Bathymetry						Study altimetry mission options Study three-satellite altimetry mission (2 repeatable orbits, 1 non-Sun-sync non-repeatable orbit)	• Ability to calculate ocean bottom topography • Increases navigation chart accuracy and ocean model predications • Increases accuracy in Tsunami predictions • Upgraded ability to forecast safe maritime passage	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Ocean Color						Lack of technology confidence in initial VIIRS instrument	• Ability to characterize the amount of live biomass (e.g. phytoplankton), turbidity, identify algal blooms, and track plumes • Slow develop a seasonal assessment of chlorophyll and turbidity within the contiguous United States coastal zone	NA	NA
Coastal Water/ Habitat						Commercial buy-study for coastal/event imager	Provides satellite observations for modeling & forecasting capabilities for ecological and biogeochemical processes in coastal ecosystem management • Ability to effectively monitor ecosystem change; increased capability to identify key trends or mitigating actions • Increased ability to quantify measurements; increased habitat prediction system uncertainty	Moderate	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Earth Radiation Budget						NPP/NPOESS C1 w/Ceres, Need follow-on capability	Improvement to global climate change predictions • Continuous satellite record of incoming and outgoing radiation; increased energy balance accuracy and climate trend identification • Upgraded capability for global and mesoscale energy balance; increases mesoscale forecast accuracy and climate trend accuracy	Low	Re-manifest earth radiation budget instrument onto NPOESS C3 and beyond or instrument on Climate Satellite free-flyer

Table 2. Measurement Areas Gap Analysis Continued

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Aerosols						NPOESS demanifested aerosol polarimeter, replace or other satellite	Improvement to global climate change predictions • Improved accuracy of aerosol optical depth; increased forecast accuracies of visibility, pollution impacts, etc. • Ability to get aerosol type and size distribution; Increases accuracy of regional predictions	Moderate	Re-manifest aerosol polarometer instrument onto NPOESS and beyond or instrument on Climate Satellite free-flyer
Ozone						Limb profiler is manifested on NPP NPOESS demanitested limb profiler, replace or other satellite	• Ability to measure ozone profile to compliment the Total Ozone measurement, leading to a increase in the ability to track ozone change and make predictions for public safety • Increased ability to distribute energy vertically in atmosphere; increases forecast skill	Moderate	Re-manifest ozone profile instrument onto NPOESS and beyond or instrument on Climate Satellite free-flyer
Solar Irradiance						NPOESS demanifested, replace or other satellite	• Continuous satellite record of solar constant observations leading to increased energy balance accuracy and related climate trend indentification • Improved capability to determine the global energy balance, Increases regional prediction accuracy	High	Re-manifest solar radiation budget instrument onto NPOESS C3 and beyond or instrument on Climate Satellite free-flyer
Carbon						Study NASA OCO mission or infrared Radiometer	Ability to quantify carbon sources and sinks • Upgrades capability to predict regional ecosystem impacts • Upgrades capacity for understanding carbon climate trends • Increases forecast accuracy for effluents and their impact	High	Feasibility study for the NASA OCO mission, including benefit analysis, to determine sensing platform
Snow Depth						Study multi-frequency radar	Increased prediction capability for water supplies, floods, weather, and climate • Ability to quantify snow depth; impacts flood and run-off prediction accuracy • Improved albedo/extent specifications; reduces albedo and temperature forecast uncertainty	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform

Table 2. Measurement Areas Gap Analysis Continued

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Ice Thickness/Extent						Study ICEsat II or Multi-frequency Radar	Increased ability to estimate the effects of increasing greenhouse gases on the future global climate • Ability to assess ice characteristics • Improved forecast skill for maritime passage • Upgraded climate trend predictions	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Tropospheric Winds						ADM/Aeolus (partial); no planned follow-on	Improved weather (including over ocean) forecast and long-term analysis of systems (including severe storm) development over oceans	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Precipitation type						No capability today, GPM follow-on required	Ability to provide all-weather information about the hydrological cycle such as latent heat release and the affect on storm dynamics, circulation and atmospheric structure • Ability to determine storm characteristics; reduces severe weather and regional forecast uncertainty • Ability to assess mesoscale system characteristics; increased regional forecast accuracy	Low	Feasibility study for a research mission, including benefit analysis, to determine sensing platform
Radio Occultation						COSMIC and GRAS partial, require follow-on	Calibration improvements, since GPSRO observations are totally independent of other atmospheric observations and are very precise • Ability to accurately specify temp and moisture profiles near tropopause and stratosphere; Upgrades global and regional model skill • Ability to measure electron density profiles; Increases communications forecast accuracy	Moderate	Participate in COSMIC Follow-on

Table 2. Measurement Areas Gap Analysis Continued

Meets
Extended
Predominantly
Continuity

Measurement	2010	2015	2020	2025	2030	Gap Remark	Impact	Risk	Required Decision
Space Environment						NPOESS inability to provide all space products (Nunn-McCurdy)	Improve understanding on how to predict changes in the solar atmosphere at the sun, and how they evolve as they expand outward into the solar system and into the Earth's magnetosphere and atmosphere. • Continues one- to three-day warning of potential geomagnetic storms • Ability to measure solar wind upstream of the Earth; Increased forecast accuracy of communications forecasts, magnetic storm predictions, scintillation predictions and hazards to personnel in space	Moderate	Commit to maintain and improve space environmental measurements
Solar Measurements						ACE sensor health in question. ACE has fuel to last to approximately 2019. The instrument needed for space weather alerts is nearing end of life No current plan for L1 operations mission – explore data buys. No ops CME capability	Increased ability to predict geomagnetic storms • Solar and coronal mass ejections can disable satellites and disrupt communication signals • Ability to improve solar warning time for communication/intel satellites, astronaut safety, and polar airline flight safety • Ability to measure solar wind upstream of the Earth; Increased forecast accuracy of communications forecasts, magnetic storm predictions, scintillation predictions and hazards to personnel in space	High	Commit to maintaining and improving space environmental measurements

Table 2. Measurement Areas Gap Analysis Concluded

Meets

Extended

Predominantly

Continuity

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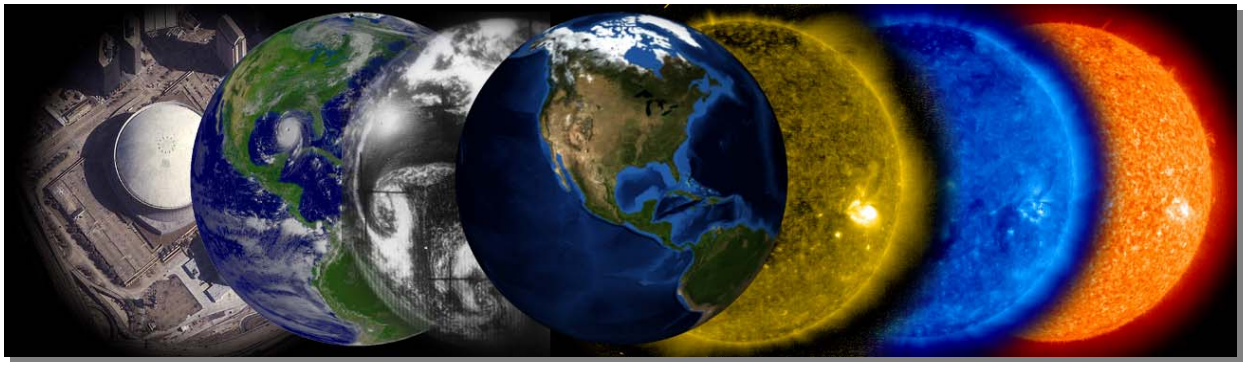

4 Satellite Investment Opportunities

The primary strategic plan investment objective is the sustainment and continuance of the NOAA's satellite services at today's capability level. The second objective is to invest in enhancements and optimizations of satellite sensors to improve constellation performance and improve satellite services. To accomplish these objectives, the funding profile has been broken down into three investment levels: Current Program, Extended Program, and Projected Program (Figure 7).

(Cost Information Removed for Public Document)

Table 3 shows how each measurement maps to specific satellite systems, sensors, and funding levels. Each of the referenced funding levels are discussed below. Un-accommodated options cover the sensors that require further study and analysis and are discussed in the recommended study section of this chapter and detailed in Appendix G.

Current Program (Budget from FY09 DOC Passback)

- GOES-N/O/P,
- GOES-R/S;
- NOAA-18/N-Prime;
- NPP/NPOESS (C1-C4)

Extended Program (Current Program PLUS)

- NPOESS Follow-on (Estimated Funding): Satellites C5 and beyond
- GOES-R Follow-on (Estimated Funding): Satellites T&U (with Advanced Sounder) plus future satellites

Projected Program (Extended Program PLUS) (Estimated Funding)

- Other Missions
  - Climate instruments Re-manifested,
  - Scatterometry (ocean vector winds),
  - Altimeter (sea surface height), and
  - Radio occultation
- Investment alternatives: Proposed budget for trade studies and analysis of alternatives
  - Determine specific solutions
  - Address unmitigated gaps, new sensor technology, and new system approaches

Figure 7. Three Investment Levels

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Measurement Areas	Other Agency		CURRENT					EXTENDED			PROJECTED		UNACCOMODATED OPTIONS
			Polar			Geostationary		Polar		Geostationary	Polar		
	Research	Operations	POES	METOP	NPOESS	NOP	R/S	METOP	NPOESS	GOES T/U +	NPOESS	OTHER NOAA	OIIP Opportunities
Imagery/Visible IR	MODIS		AVHRR	AVHRR	VIIRS	IMAGER	ABI	FO	FO	FO			
Imagery/Visible MW					MIS				FO				
Atm Temp Profiles			HIRS/ AMSU	IASI/ AMSU	CrIS ATM	Sounder	ABI	FO	FO	Adv Sounder			
Atm Moisture Profiles			HIRS/ AMSU	MHS/ IASI/ AMS	CrIS ATM	Souder	ABI	FO	FO	Adv Sounder			
Precipitation Type	TRMM/ GPM												GPM FO
Lightning							LM			FO			
Soil Moisture		SSMIS			MIS				FO				SMAP
Ocean Surface Vector Wind	QuikSCAT			ASCAT	MIS				FO			QuikScat FO	
Sea Surface Height	Jason											OSTM/ Jason 3/4	
Bathymetry													Non Sun Sync Altimeter
Ocean Color	MODIS/ VIIRS				VIIRS				FO				
Coastal Waters/Habitat													
Earth Radiation Budget	CERES				CERES (C1 only)						ERBS		
Aerosols/ Polarimetry											APS		
Ozone Profiles	OMPS Limb		SBUV	GOME	OMPS Nadir/ Limb			FO	FO		Omps Nadir/ Limb		
Solar Irradiance											TSIS		CLARREO
Carbon					IASI/CrIS								OCO
Snow Depth													IceSat II
Ice Thickness & Extent													IceSat II
Tropospheric Winds													Lidar
Radio Occultation		COSMIC		GRAS				FO					Radio Occultation
Solar Measurements	ACE & Glory					SXI	SUVI		SUV	FO			Solar Wind
Space Environment			SEM	SEM	SEM (pm only)	SEM	SEISS		FO	FO			Coronograph
Sea Surface Salinity*													Aquarius

<$1.5B

<$1.8B

<$2.4B

**Aquarius relates to Sea Surface Salinity (SSS), a distinct measurement, and is not part of the 23 measurement areas analyzed.*

Table 3. Satellite Program Budget Overview **NOTE: Colors match Figure 10, Projected Options**

4.1 Current Program

Investment funding will maintain the current baseline suite of satellite capabilities for the GOES and POES systems without follow-on satellites (GOES T-series or NPOESS Follow-on series). A summary of the current investment level includes the satellites (operation and acquisition, including launch) and their operational support and the projected program completion profile: current POES, GOES, and Satellite Services. (**Error! Reference source not found.**)

The **NOAA Polar-Orbiting System** consists of NOAA's POES including the provision of U.S. instruments for flight on the European Polar System satellites known as MetOp and the NPOESS. As part of a cooperative agreement with NOAA, the MetOp series of satellites within the EUMETSAT will carry U.S. sensors and provide data services coverage from a mid-morning polar-orbit through 2020. POES is NOAA's current operational polar system, with one satellite left to launch in the series (NOAA-N Prime). The POES system provides daily global observations of weather patterns and environmental measurements of the Earth's atmosphere, its surface and cloud cover, and the proton and electron flux at satellite altitude and provides long-term data sets for climate monitoring and assessment and climate change predictions.

The **POES Ground System** is a "System-of-Systems" that comprises the end-to-end framework for collecting, processing, and disseminating critical environmental data and information from the POES satellites. Operational elements are located at Fairbanks, Alaska; Wallops, Virginia; and, Suitland, Maryland.

NPOESS through C4 without climate sensors: The NPOESS system will consist of U.S satellites in two orbits (early morning and afternoon). However, NOAA requires three orbits to satisfy the 4-hour global satellite observation refresh requirement. Therefore, NOAA will use data from the MetOp satellites for the mid-morning orbit, while providing flexibility to reassign DMSP satellites to the mid-morning orbit depending on the health of the constellation. Under the restructured program schedule, the NPOESS launch dates are 2013 for C1, 2016 for C2, 2018 for C3, and 2020 for C4. The NPOESS Preparatory Project (NPP) launch date is September 2009. Data from NPP will be used not only operationally but as a risk-reduction effort to transition NPOESS allowing mission continuity with POES.

NPOESS Data Exploitation (NDE): The NDE project will develop and implement capabilities to process and distribute NPOESS products and services, starting with the NPP satellite, once the data have been delivered to NOAA. NPOESS and NPP are part of the new environmental satellite program that promises to improve our observations of the earth, atmosphere, oceans, and space environment. To realize the benefits of NPOESS data, NOAA must implement capabilities to process NPOESS data records into useful products that meet the requirements of NOAA's operational centers and civilian users. For example, NDE will be able to derive carbon-based products such as methane, carbon dioxide and carbon monoxide from NPOESS observations. By producing a better estimate of the gases, NDE will help NOAA's National Weather Service to remove biases and improve weather forecasts. NDE will also assist NOAA's Climate Prediction Center by providing global estimates of these gases.

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The **NOAA Geostationary Operational Environmental System** consists of satellites and sensors in geostationary orbit and the ground systems that support them (under development or in acquisition).

NOAA GOES-N Series satellite program is the current system that includes the observing platform (satellite and sensors), command and control of the on-orbit assets, spacecraft unique ground system, and interface to NOAA ground facilities. GOES observations allow continuous weather monitoring from the same angle, enabling the detection and tracking of severe storms, atmospheric moisture gradients, mesoscale weather systems, clouds, and aerosols—capabilities that cannot be achieved from a non-stationary orbit without increased error rates and lost data segments. The system maintains an on-orbit spare to complement the two operational GOES satellites. This on-orbit spare philosophy allows NOAA to quickly replace a failed satellite by re-positioning an on-orbit satellite.

The **GOES Ground System** is a "System-of-Systems" that comprises the end-to-end framework for collecting, processing, and disseminating critical environmental data and information from the satellites. It supports the launch, activation, and evaluation of new satellites and the in-depth assessments of satellite data quality. Data from the satellites are received at ground facilities, where the data are processed to monitor and control the satellite and to generate products that are used by NOAA, its users, and the world meteorological community. The GOES ground system consists of components at the Satellite Operations Control Center (SOCC) at Suitland, Maryland; Command and Data Acquisition (CDA) facilities at Wallops, Virginia, and Fairbanks, Alaska; and Wallops Backup (WBU) facility at NASA Goddard Space Flight Center (GSFC) in Greenbelt, Maryland.

GOES R and S—without advanced sounder or coastal waters sensor: The GOES-R will be comprised of improved spacecraft and sensor technologies that will provide more timely and accurate weather forecasts and improve support for the detection and observations of meteorological phenomena that directly affect public safety, protection of property, and economic health and development. The first launch of the GOES-R series satellite is 2014. With the launch of GOES-R, NOAA will begin a new era of geostationary remote sensing.

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4.2 Extended Program

This investment opportunity includes a continuous and sustainable capability for GOES and POES systems, but does not fund critical gaps. In summary, this investment includes the following:

- Current program (see Section 4.1)
- NPOESS Follow-on: Estimate for C5 and beyond
- GOES-R Follow-on: Estimate for T&U (with Advanced Sounder) plus future satellites
- Ground system upgrades: Transition towards an integrated process, generation, product sustainment, and distribution system that can support multiple satellites from multiple locations. An integrated architecture will provide NESDIS Satellite Operations and research offices with the maximum flexibility and efficiency to sustain and operate the nation's critical environmental satellite systems.
- Investment Opportunities: Trade Studies and Analysis of Alternatives to determine specific solutions to address measurement gaps (see Section 4.4)

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4.3 Projected Program

This investment opportunity maintains the current base funding profile, provides continuity and sustainability, and expands capabilities. In summary, this investment includes the following:

- Current program (see Section 4.1)
- Extended program (see Section 4.2)
- Other missions: Estimates for re-manifested climate sensors, plus scatterometry (ocean vector winds), altimeter (sea surface height), and radio occultation (indirect measurement of temperature, pressure and water vapor in the stratosphere and the troposphere) missions
  - *Re-manifested Climate Sensors*.
    - Total Solar Irradiance Sensor (TSIS) monitors the energy of the sun incident on Earth and can only be determined above the atmosphere. Any interruption of the 28-year data record of Total Solar Irradiance jeopardizes the ability to confidently resolve small changes in fundamental climate change attributes.
    - Clouds and the Earth's Radiant Energy System (CERES) Earth Radiation Budget Sensor (ERBS) monitors from the surface through the top-of-atmosphere energy budget that maintains climate and can only be determined from satellites.
    - Ozone Mapping and Profiler Suite (OMPS)-Limb sensor measures stratospheric ozone, the lack of which can be harmful to humans and other organisms.
    - Aerosol Polarimetry Sensor (APS) monitors the effects of aerosol properties on global temperature.
  - *Scatterometry (Ocean Surface Vector Winds)*: A high temporal and spatial resolution scatterometry mission would benefit NOAA by providing accurate tropical cyclone wind field intensity and distribution measurements for improved warning times and intensity forecasts. QuikSCAT, a research satellite that is currently more than four years beyond its design life, revealed that extra-tropical storms reach hurricane force intensity more often than previously thought and that conditions last on the average of 24 hours.
  - *Altimetry (Sea Surface Height)*: An altimetry mission would benefit NOAA/NESDIS and other entities by providing operational continuity for global sea surface height (initiated by Topex-Poseidon and Jason-1) to maintain the climate record for determining accurate estimates of global sea level rise, decadal variability, El Niño/La Niña predictions, coastal forecasts, and hurricane intensification forecasts.
  - *Radio Occultation (indirect measurement of temperature, pressure and water vapor in the stratosphere and the troposphere, as well as electron densities in the upper atmosphere)*: The existing COSMIC-1 satellite constellation has a predicted end-of-life in 2011; there will be a loss of ~3000 global atmospheric profiles per day that are currently being used operationally at NCEP in Numerical Weather Prediction (NWP) models.

In summary, an investment profile that includes advancing NOAA's capabilities to cover critical satellite remote sensing gaps (such as climate sensors, altimetry, and scatterometry) and maintaining data continuity will require a committed program.

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4.4 Recommended Studies for Improvement

Today's satellites provide more environmental information than ever before; however, NOAA's satellite program cannot stagnate. Continued advancement is needed to improve severe storm warnings, climate forecasts, and more. Table 4 delineates recommended candidates for trade studies, technology advancement, and satellite system approach; a detailed analysis is provided in Appendix G. Candidates in **bold** font indicate the recommended near-term actions. Remaining candidates (*watch items*) will be reviewed annually to determine whether they should remain on the list and whether research indicates enough development/advancement to move to a near-term candidate state. NOAA decision makers can use the resulting analysis from these candidate studies to consider new start, modification, and no-start determinations.

Each of the mentioned candidates' impact cross-cuts a broad range of data products, leading to improvements in forecasting and trending. For instance, improvements to ocean event (such as hurricanes and tsunamis) track projections and intensity forecasts, precipitation types, and atmospheric profiles (both temperature and moisture) could be realized with technology advancement in three-dimensional (3-D) wind profilers, special event imagers or sounders, Geo-microwave sounders, altimeters, and scatterometers.

Improvements to ground system efficiency are possible with a transition towards an integrated processing, generation, and distribution system. Such integration would not only provide a dedicated geostationary or polar product, it would also be able to produce a combined or blended product (merged information). Additionally, an integrated process will enhance calibration and validation efforts across the satellite program or network and within the data products for improved data product accuracy and consistency.

Each candidate will go through the NOAA Technical Planning and Integration Office (TPIO) and NOAA Observing Systems Council (NOSC) validation process to access the added benefit to the NOAA users. Assessment/analysis will provide NOAA leadership the information needed to determine whether a "specified improvement" should be added to the NOAA space observation platform and to optimize the improvement for the appropriate orbit and mission.

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TRADE STUDIES	SENSOR TECHNOLOGIES	SYSTEM APPROACHES
Climate Sensors: Re-manifest onto existing spacecraft or free-flying climate satellite) **Ocean Mission Optimization**: combined Jason and Altimeter Mission **Bathymetry**: feasibility of three satellite constellation with one being a non-sun synchronous and non-repeat orbit **Coastal Waters/Habitat**: feasibility **Precipitation Typ**e: determine sensing platform **Space Environment**: Solution set options for the collection of space measurements from various orbits (i.e., L1, Geostationary, Polar, etc.) *Soil Moisture: feasibility* *Snow Depth: feasibility* *Ice Thickness: feasibility* *Tropospheric Winds: feasibility* *Very High Resolution Sensor: Solution set options for ecosystem and special event support*	**Special Event/Coastal Imager** (ACE, HYSPIRI) **3-D Doppler Wind Lidar** **Geo-Microwave** (soundings/stability) **Solar Spectral Irradiance** (CLARREO) **Ozone Profiler** *Far Infrared Monitoring* *Differential Absorption Lidar* *Laser Altimetry* *Radars (LEO/GEO, freq. by application)* *Wide Swath Altimeter* *Climate Reference Sensor* *Bidirectional Radar* *Sensor Integration Opportunities* *Sparse Aperture Techniques*	**Integrated architecture** including IT security and interoperability **Transaction-based archive and access** **Integrated Cal/Val System** **Address instrument phasing** to provide continuity **Apply OSSE and High Performance Computing optimizations** **Data Compression** *Optimum number of satellites/sensors to purchase* *Flexible launch* *Satellite Cross-link (Communication)* *Satellite/instrument configuration and constellations (MEO, Molniya, L1)* **REQUIREMENTS TRANSLATION/ACQUISITION APPROACH** **Commercial/partner instrument launch** **Optimization Studies** (compare satellite with other platforms — space versus ground/ airborne/sea-based platforms)

Table 4. Sensor and System Trades

Candidates in **bold** font indicate the recommended near-term actions. Candidates in *italics* are watch items, annually reviewed for technology advancement.

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5 Conclusion and Next Steps

The Strategic Satellite Plan provides annual long-range guidance for developing the Fiscal Year (FY) 2010-19 Satellite Sub-Goal Program and includes the following:

- A recommended strategic investment for the Satellite Sub-goal (see Section 5.4)
- An overarching vision of the satellite constellation and its capitalization
- A reasonably level fiscal profile (in current year dollars) containing enough flexibility to adjust to priority changes and schedule modifications
- A plan for evolving the current satellite management and support structures into capabilities directly relevant with NOAA's changing mission and business processes

Implementing the strategic satellite plan will require a coordinated effort by NOAA and other agencies where appropriate both to ensure continuity of current satellite observation missions and to address critical satellite gaps in coverage and performance.

These efforts must examine the full range of capability, technical, and performance risk and cost through a series of well managed trades/studies and analyses. NOAA must institute these processes by implementing the following four efforts (described in greater detail below):

- Set NOAA Satellite Sub-Goal Priorities
- Complete NOAA Corporate-level Actions
- Ensure Goal Team and Program Participation
- Quantify Funding Plans

The required commitments or decisions needed to execute the satellite plan are described below and in detail in the Appendices E and F.

5.1 NOAA Satellite Sub-Goal Priorities

NOAA will continue developing a satellite system following these near-term fundamental priorities to ensure continuity of existing measurements (when feasible) and to re-manifest climate sensors (where funding and capability exists).

- Add capability to satisfy ocean requirements (considering technical risk and funding).
- Develop Advanced Sounding capability on the next generation of GOES satellites.
- Ensure Space Environment measurements are fully considered.
- Apply the CORL as the standard for observational measurement requirements.

5.2 NOAA at the Corporate-Level

At the corporate level, NOAA will focus on the following fundamental priorities:

- Institutionalize NOAA's satellite program by annually updating the plan and using the PPBES to ensure full NOAA-wide participation
- Develop processes to complete NOAA-wide measurement prioritization of the mission-critical requirements identified and validated in the CORL
- Goal Teams and Programs

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For goal teams and programs, NOAA will focus on the following fundamental priorities:

- Ensure requirements are updated and validated in the CORL (Programs)
- Work with algorithm developers, ground systems planners, and archive and access programs to achieve strategic optimization of a GEO-IDE compliant ground system (Goals and Programs)
- Collaborate with the Satellite Sub-Goal to prioritize requirements and weigh options (Goals and Programs)
- Provide feedback about how the satellite plans satisfy requirements

5.3 NOAA Funding Efforts

NOAA funding efforts require the following actions:

- Develop cost profile estimates for satellite missions.
- Identify and provide funds to conduct analyses of alternatives and system feasibility studies.
- Define and analyze research-to-operations transition trades needed to optimize the observation constellation.

5.4 Projected Actions Inherent in Satellite Plan

The following projected actions are inherent in NOAA's Satellite Plan:

- Continue the geostationary and polar orbiting satellite systems.
- Establish Satellite Altimetry Follow-On System with a 2014 launch date (replacement for NASA Jason-1/Ocean Surface and Typography Mission (OSTM) mission).
- Begin "early new start" trade study for Satellite Scatterometry Mission.
- Start negotiations with ESA/EUMETSAT for upgrades to Imagery sensors (VIIRS-like sensors) for follow-on missions.
- Review spacecraft options for each re-manifested climate sensor and the alternative solution for a free flying climate satellite.
- Procure advanced sounding capability for GOES T/S.
- Develop the Integrated NOAA Architecture for satellites.
- Support the Archival System (CLASS).
- Support calibrating satellite data from all satellite sources and validating the products derived from the data.
- Procure solar wind and coronagraph measurements and continue efforts to recover reduced space weather capabilities on NPOESS.

Additional decision information is detailed in Appendix G.

5.5 Conclusion

This strategic satellite plan provides NOAA a comprehensive view of the realities and challenges it faces over the next two decades. The plan analyzed and synthesized NOAA's most critical satellite requirements while evaluating capabilities to satisfy significant Earth observing

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limitations. This first report on the "state of the NOAA Satellite system" opens the door for future evaluations and assessments and within a baseline framework.

Overall, NOAA achieves the majority of the environmental satellite observations required. However, as sensor technology has advanced, the requirements necessarily evolve as more cost-effective measurements can be acquired from satellites. The plan addresses observation requirements that can be cost effectively satisfied with satellites. The plan has established a baseline for sustaining critical (unique) satellite capabilities well into the next two decades. The plan identified several significant shortcomings of the existing systems and near-term plans while highlighting alternatives to either complement or mitigate the associated measurement gaps. These significant limitations include (but are not limited to) Coastal Habitat and related Ecosystem measurements. New capabilities are addressed and the plan recommends specific trade studies to evaluate the potential evolution of new technologies into the operational satellite observation systems. NOAA strongly recommends instituting a formal Operational Instrument Improvement Program with NASA for improved research-to-operations transition capability.

As a living document, this plan will be reviewed and supplemented annually to coincide with the appropriate PPBES insertion points. NOAA Programs will require this guidance for preparing their Program Operating Plans, which support the development of NOAA's budget. NOAA's Program, Planning, and Integration Office can apply the strategic plan information in preparing both the Annual Guidance Memorandum and the Strategic Portfolio. NOAA Goals should apply this information while preparing their Program Plans and associated alternative/adjustment priorities. Finally, the Office of Program Analysis and Evaluation should ensure this plan is considered while developing the Program Decision Memorandum.

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Appendix A Acronyms

Acronyms used in this report are listed below.

ABI	Advanced Baseline Imager (NOAA)
ACE	Advanced Composition Explorer (NASA)
ACE	Aerosol/Clouds/Ecosystem Mission (NASA)
ADCS	Advanced Data Collection System (NOAA)
ADM-Aeolus	Atmospheric Dynamics Mission Aeolus (NASA)
AIRS	Atmospheric Infra-Red Sounder (NASA)
ALT	Altimeter
ALTIKA	Altimeter Ka-Band (France)
AMSR	Advanced Microwave Scanning Radiometer (NASA)
AMSU-A	Advanced Microwave Sounding Unit – A (Europe)
AMSU-B	Advanced Microwave Sounding Unit – B (Europe)
AoA	Analysis of Alternatives
AOML	Atlantic Oceanographic and Meteorological Laboratory (NOAA)
APS	Aerosol Polarimetry Sensor (NOAA)
ASAR	Advanced Synthetic Aperture Radar (Europe)
ASCAT	Advanced Scatterometer (Europe)
ASCENDS	Active Sensing of CO2 Emissions over Nights/Days/Seasons (NASA)
ATMS	Advanced Technology Microwave Sounder (NOAA)
AVHRR	Advanced Very High Resolution Radiometer (Europe)
C3	Command, Control, Communications
Cal/Val	Calibration and Validation
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization (NASA)
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (NASA)
CDA	Command and Data Acquisition
CEOS	Committee on Earth Observation Satellites
CERES	Clouds and the Earth's Radiant Energy System (NASA)
CMA	China Meteorological Administration
CPR	Cloud Profiling Radar (NASA)
CLT	Climate Goal (NOAA)
CLASS	Comprehensive Large Array-data Stewardship System (NOAA)
CLARREO	Climate Absolute Radiance and Refractivity Observatory (NASA)
Cloud Sat	Cloud Satellite (NASA)
CME	Coronal Mass Ejection (NASA)

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CMIS	Conical-scanning Microwave Imager/Sounder (NOAA)
CNES	Centre National d'Etudes spatiales (France)
CO_2	Carbon Dioxide
CORL	Consolidated Observational Requirements List
COSMIC	Constellation Observing System for Meteorology, Ionosphere and Climate (Taiwan)
CrIS	Cross-track Infrared Sounder (NASA)
C&T	Commerce &and Transportation Goal (NOAA)
DESDynI	Deformation, Ecosystem Structure and Dynamics of Ice (NASA)
DMSP	Defense Meteorological Satellite Program (DoD)
DOC	Department of Commerce
DoD	Department of Defense
DPR	Dual-frequency Precipitation Radar (Japan/NASA)
Earth-CARE	ESA's cloud &and aerosol mission (Europe)
ECO	Ecosystems Goal (NOAA)
EOS-Aqua	Earth Observing System Aqua (NASA)
EOS-Aura	Earth Observing System Aura (NASA)
EOS-Terra	Earth Observing System Terra (NASA)
ERBS	Earth Radiation Budget Sensor (NOAA)
ESA	European Space Agency
ESRL	Earth System Research Laboratory (NOAA)
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
EUVS	Extreme Ultra-Violet System (NOAA)
EXIS	Extreme ultraviolet and X-ray Irradiance Sensors (NOAA)
FEMA	Federal Emergency Management Agency
FO	Follow-On
FY	Fiscal Year
FY-#	Feng Yun (Chinese polar- orbiting satellite)
GACM	Global Atmospheric Composition Mission (NASA/Japan)
GCOM	Global Climate Observation Mission (Japan)
GCOS	Global Climate Observing System
GEO	Group on Earth Observing
GEO	Geostationary
GEO-CAPE	Geostationary Coastal &and Air Pollution Events Mission (NASA)
GEO-IDE	Global Earth Observations-Integrated Data Enterprise environment
GEOSS	Global Earth Observing System of Systems
GFDL	Geophysical Fluid Dynamics Laboratory (NOAA)

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GLM	Geostationary Lightning Mapper (NOAA)
GLAS	Geoscience Laser Altimeter System (NASA)
GMI	GPM Microwave Imager (Japan/NASA)
GNSS	Global Navigation Satellite System
GOES	Geostationary Operational Environmental Satellite
GOME	Global Ozone Monitoring Experiment (Europe)
GOMOS	Global Ozone Monitoring by Occultation of Stars (Europe)
GOSAT	Greenhouse gases Observing SATellite (Japan)
GPM	Global Precipitation Measurement
GPS	Global Positioning System
GPSRO	Global Positioning System Radio Occultation
GRACE	Gravity Recovery And Climate Experiment (NASA)
GRAS	GNSS Receiver for Atmospheric Sounding (Europe)
GSFC	Goddard Space Flight Center (NASA)
HIRS	High-resolution InfraRed Sounder (NASA)
HyspIRI	Hyperspectral InfraRed Imager (NASA)
IASI	Infrared Atmospheric Sounding Interferometer (European)
ICESat	Ice, Cloud, and land Elevation Satellite (NASA)
IGOS	Integrated GPS Occultation Receiver
IJPS	Initial Joint Polar System
IMD	Indian Meteorological Department
INSAT	Indian meteorological SATellite
IPO	Integrated Program Office (NOAA/DoD/NASA)
IRAS	InfraRed Atmospheric Sounder
ISO	International Organization for Standardizations
ISRO	Indian Space Research Organisation
IT	Information Technology
JAXA	Japan Aerospace EXploration Agency
JCSDA	Joint Center for Satellite Data Assimilation (NOAA)
JMA	Japan Meteorological Agency
JPS	Joint Polar System
L1	LaGrange Orbit
LDCM	Landsat Data Continuity Mission (US)
LEO	Low Earth Orbit
LIDAR	LIght Detecting and Ranging
LW	Long Wave

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Mag	Magnetometer
Megha-Tropique	Megha meaning cloud in Sanskrit and Tropiques meaning tropics in French (France)
MEO	Mid-Earth Orbit
MERIS	Medium Resolution Imaging Spectrometer (European)
MetOp	Meteorological Operational (satellite [EUMETSAT])
MHS	Microwave Humidity Sounding
MIS	Microwave Imager/Sounder (NOAA)
MLS	Microwave Limb Sounder (NASA)
MODIS	MODerate-resolution Imaging Spectro-radiometer (NASA)
MSG	Meteosat Second Generation (Europe)
MTG	Meteosat Third Generation (Europe)
MTSAT	Multi-functional Transport SATellite (Japan)
MW	Micro-Wave
MWR	Micro-Wave Radiometer (China)
MWRI	Micro-Wave Radiation Imager (China)
MWTS	Micro-Wave Temperature Sounder (China)
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NCDC	National Climate Data Center (NOAA)
NCDDC	National Coastal Data Development Center (NOAA)
NCEP	National Centers for Environmental Prediction (NOAA)
NDE	NPOESS Data Exploitation (NOAA)
NEC	NOAA Executive Committee
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NEP	NOAA Executive Panel
NGDC	National Geophysical Data Center (NOAA)
NIR	Near Infrared
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center (NOAA)
NOSC	NOAA Observing Systems Council
NPOESS	National Polar-orbiting Operational Environmental Satellite System (NOAA/DoD)
NPP	NPOESS Preparatory Project (NOAA/DoD/NASA)
NRC	National Research Council
NWP	Numerical Weather Prediction (NOAA)
OCM	Ocean Color Monitor (NASA)

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OCO	Orbiting Carbon Observatory (NASA)
OFCM	Office of the Federal Coordinator for Meteorology
OIIP	Operational Instrument Improvement Program (NOAA/NASA)
OLC	Ocean and Land Color (Europe)
OLS	Operational Linescan System (DoD)
OMI	Ozone Monitoring Instrument (NASA)
OMPS	Ozone Mapping and Profiler Suite (NOAA)
OSSE	Observing System Simulation Experiments
OSTM	Ocean Surface and Topography Mission (NASA)
OSVW	Ocean Surface Vector Winds
PA&E	Program Analysis and Evalution (NOAA)
PALSAR	Phased Array type L-band Synthetic Aperture Radar (Japan)
PARASOL	Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a LIDAR (France)
PATH	Precipitation and All-Weather Temperature and Humidity (NASA)
PB	President's Budget
PDRR	Program Definition and Risk Reduction
PMEL	Pacific Marine Environmental Laboratory (NOAA)
POES	Polar-orbiting Operational Environmental Satellite (NOAA)
POLDER	Polarization and Directionality of the Earth's Reflectances (France)
POP	Program Operating Plan (NOAA)
PPBES	Planning, Programming, Budgeting &and Execution System
PR	Precipitation Radar (NASA)
QuikSCAT	Quick Scatterometer (NASA)
RO	Radio-occultation
SAR	Synthetic Aperture Radar
SARAL	Satellite with ARgos and ALtiKa (India/France)
SARSAT	Search and Rescue Satellite-Aided Tracking (NOAA)
SBUV	Solid Backscatter Ultra Violet radiometer (NOAA)
SCAT	Scatterometer
SCIAMACHY	Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (Europe)
SCLP	Snow and Cold Land Processes
SeaWiFS	Sea-viewing Wide Field-of-view Sensor (NASA)
SEISS	Space Environmental In-Situ Suite (NOAA)
SEM	Space Environmental Monitor (NOAA)
SESS	Space Environmental Sensor Suite (NOAA)
SEVIRI	Spinning Enhanced Visible and InfraRed Imager

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SMAP	Soil Moisture Active Passive (NASA)
SMOS	Soil Moisture and Ocean Salinity mission (Europe)
SO_2	Sulfur Dioxide
SOA	Service Oriented Architecture
SOCC	Space Operations Control Center (NOAA)
SORCE	SOlar Radiation and Climate Experiment (NASA)
SPOT	Satellite Pour l'Observation de la Terre (France)
SSH	Sea Surface Height
SSMIS	Special Sensor Microwave – Imager/Sounder (DoD)
SSS	Sea Surface Salinity
STEREO	Solar-Terrestrial Relations Observatory (NASA)
SUV	Solar Ultra Violet
SUVI	Solar Ultra Violet Imager (NOAA)
SW	Short Wave
SWOT	Surface Water and Ocean Topography (Europe)
SXI	Solar X-ray Imager (NOAA)
TBD	To Be Determined
TMI	TRMM Microwave Imager (NASA)
TPIO	Technical Planning and Integration Office (NOAA)
TRMM	Tropical Rainfall Measuring Mission (NASA)
TSIS	Total Solar Irradiance Sensor (NOAA)
USGEO	United States Group on Earth Observing
UV	Ultraviolet
UV/VIS/NIR	Ultraviolet/Visible/Near Infrared
VADM	Vice Admiral
VIIRS	Visible/Infrared Imager Radiometer Suite (NOAA)
VIRR	Visible and InfraRed Radiometer (China)
VIS/IR	Visible/InfraRed
WBU	Wallops BackUp (NOAA)
WMO	World Meteorological Organization
WRF	Weather Research and Forecast model (NOAA)
WW	Weather &and Water Goal (NOAA)
XOVWM	Extended Ocean Vector Wind Mission (NASA)
XRS	X-ray Sensor (NOAA)

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Appendix B Notable Legislative Regulations

The NOAA Satellite program, like NOAA itself, is driven by appropriate guidance, regulations and laws. A sampling of the most significant laws (U.S.C.), Executive Orders/Policy and interagency/international agreements are provided below. While these laws, directives and agreements are not an exhaustive listing, they represent the significant requirements levied by the U.S. Government and stakeholders on development of this report.

15 U.S.C. § 313 National Weather Service Organic Act and Global Change Research Act (2003): NOAA satellites provide enhanced near-real-time information support timely and more accurate forecasts in support of commerce, agriculture, navigation, etc. This same data is used to evaluate the climatic conditions of the United States when evaluated over extended periods of record.

Presidential Decision Directive, NSPD 15 U.S. Commercial Remote Sensing Space Policy (2003): The direction to "advance and protect U.S. national security and foreign policy interests by maintaining the nation's leadership in remote sensing space activities, and by sustaining and enhancing the U.S. remote sensing industry." is clearly is a factor in desiring to implement a robust satellite program.

33 U.S.C. § 883j Ocean Satellite Data: Directs the NOAA Administrator to take actions, including the sponsorship of applied research, necessary to assure future availability and usefulness of ocean satellite data to the maritime community.

49 U.S.C. § 44720 Meteorological Services to Support Aviation: The Department of Commerce, through NOAA, is tasked to provide meteorological services necessary for the safe and efficient movement of aircraft in air commerce. Environmental satellite data plays a crucial role in aviation support.

16 U.S.C § 1801 et seq. Magnuson-Stevens Fishery Conservation and Management Act: "The collection of reliable data is essential to the effective conservation, management, and scientific understanding of the fishery resources of the United States." Satellites are an indispensable weapon in combating one of the greatest long-term threats to the viability of commercial and recreational fisheries: the continuing loss of marine, estuarine, and other aquatic habitats.

Energy Bill Act of 2005 Title XVI (Climate Change): Provides guidance to consider additional inter-satellite calibration of sensors and the development of improved product suites that assist in the preparation of a national strategy to promote the deployment and commercialization of greenhouse gas reducing technologies and practices, as well as, monitor the changing characteristics of the Earth's climate.

15 U.S.C. § 313c Inland Flood Forecasting and Warning Systems Act (2002). Authorizes NOAA (through research, modeling, training and outreach) to enhance the capability to accurately forecast inland flooding, including flooding cased by coastal and ocean storms.

Interagency Agreement for Meteorological Services

Among the **Bureau of Land Management, Bureau of Indian Affairs, U.S. Fish and Wildlife Services, National Park Service of the United States Department of the Interior, the Forest**

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Service of the United States Department of Agriculture, and the National Weather Service of the United States Department of Commerce.

International Search and Rescue Satellite System Agreement (COSPAS-SARSAT): Search and Rescue uses satellites in low Earth and geostationary orbits to detect and locate aviators, mariners, and land-based users in distress.

Presidential Decision Directive 62 Critical Infrastructure Protection: Critical infrastructures are those physical and cyber-based systems essential to the minimum operations of the economy and government. They include, but are not limited to, telecommunications, energy, banking and finance, transportation, water systems and emergency services, both governmental and private.

15 U.S.C. §§ 5601-5672, Subchapter VI, §§ 5671-5672 Land Remote Sensing Policy Act of 1992: Prohibits the commercialization of weather satellites.

15 U.S.C § 313 note) Public Law No 98-8, Title I, § 104 97 Stat 34 (Mar 24, 1983) Prohibition on disposition of satellite facilities

Public Law No. 105-383, Title VI, 112 Stat. 3447 (16 U.S.C. § 1451 note) Harmful Algal Bloom and Hypoxia Research and Control Act of 1998: Authorizes DOC to conduct research, education, and monitoring activities related to prevention, reduction, and control of harmful algal blooms and hypoxia.

16 U.S.C. §§ 6401-6409 Coral Reef Conservation Act: The act is intended to restore coral reef ecosystems, promote wise management, develop sound scientific information, assist others in preserving reefs, provide financial resources, and provide a mechanism for funneling private funds to coral reef conservation projects.

Office of the Federal Coordinator for Meteorology (OFCM) operations plans

NOAA satellites provide data and services in support of the OFCM plans. Satellite data products and services support the operational plans listed below by providing timely, accurate, and relevant satellite data at all hours of the day and night, providing effective perspectives of the situation from which efficient decision-making can occur.

National Severe Local Storms Operations Plan B May 2001

National Winter Storm Operations Plan B November 2000

National Hurricane Operations Plan B May 2003

Federal Plan for Meteorological services and supporting Research B June 2002

Environmental Support Plan for Homeland Security B under development

The Federal Emergency Management Agency's (FEMA)/ Federal Response Plan: The plan implements the Robert Stafford Disaster Relief and Emergency Assistance Act. The Federal Response Plan tasks the Department of Commerce with acquiring weather data, forecasts, and emergency information, providing information on natural resources, predicting pollution movement, and providing information on meteorological, hydrological, ice, and oceanographic conditions.

North America-Europe Data Exchange Agreement: This agreement seeks to maintain and improve the exchange of meteorological data and products between Europe and North America, for use in operational weather forecasting and related activities.

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Agreement Between the **United States National Oceanic and Atmospheric Administration and the European Organisation for the Exploitation of Meteorological satellites** on An Initial Joint Polar-orbiting Operational Satellite System

Basic Agreement between the **National Aeronautics and Space Administration and the U.S. Department of Commerce** concerning collaborative Programs, 1998: Defines principles and guidelines in areas related to environmental satellite programs, specifically including those activities related to the development of space-based capabilities (both the development of new instrumentation, flight opportunities and enhancements to existing systems), data and information systems, the coordination of research and analysis activities and other areas of collaboration.

15 CFR Part 960 NOAA Regulations on the Licensing of Private Land Remote-Sensing Space Systems (2000): These regulations implement the provisions of the 1992 Act, as amended by the 1998 Commercial space Act, and the Presidential Policy announced March 10, 1994. They are intended to facilitate the development of the U.S. commercial remote sensing industry and promote the collection and widespread availability of Earth remote sensing data, while preserving essential U.S. national security interests, foreign policy and international obligations.

Joint Transition Activities Agreement: This agreement was signed in June 2003 by NOAA and EUMETSAT to continue access to environmental data collected by each other's satellites and calls for the parties to begin preparing for a future joint polar system post 2020.

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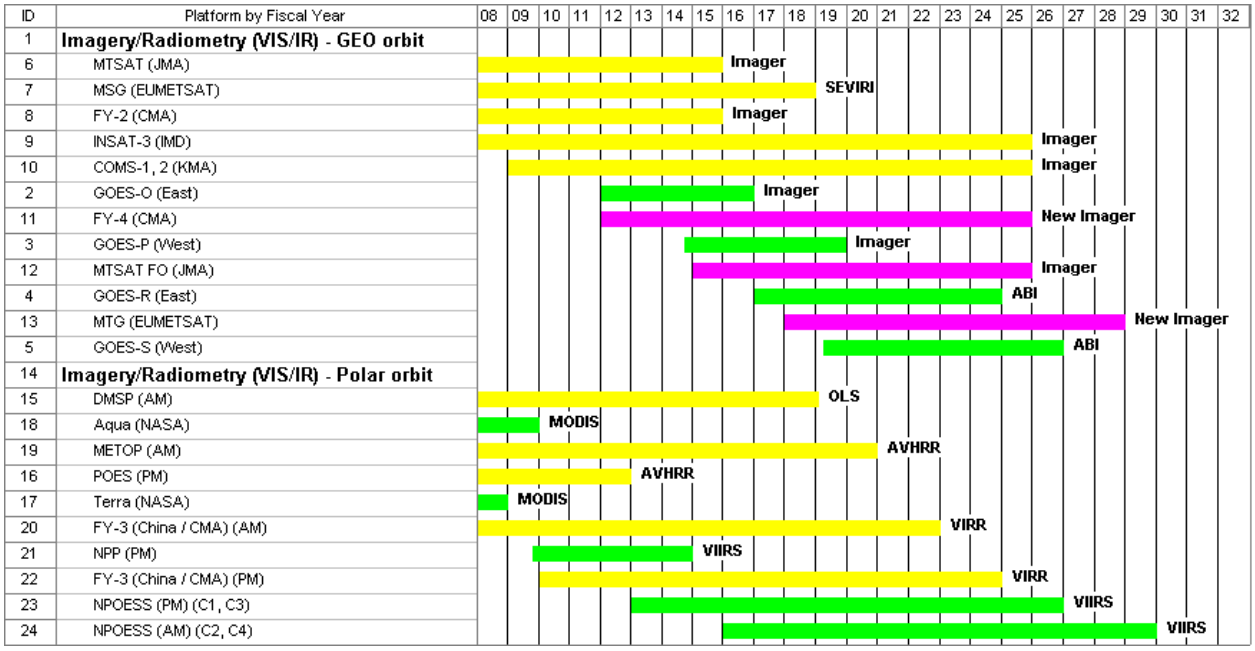
Appendix C Remote Sensing Satellite Flyout Charts: 2010-2025

Defining current and projected environmental satellite missions was a critical step in determining both potential gaps and possible alternatives for required NOAA measurements. Charts (termed 'Flyout Charts') were developed to assist in making optimal use of remote sensing satellite data from all sources (NOAA, NASA, and International), broken out by the 23 measurement areas and orbits (see charts below). Each satellite/instrument is color-coded as follows:

Meets Requirement (green)—Performance at or above threshold mission requirements (with consideration for the time evolution of requirements)

Proposed (purple)—Projected new start or follow-on program.

Partially Meets Requirement (yellow)—Performance less than the threshold mission requirement (with consideration for the time evolution of requirements)



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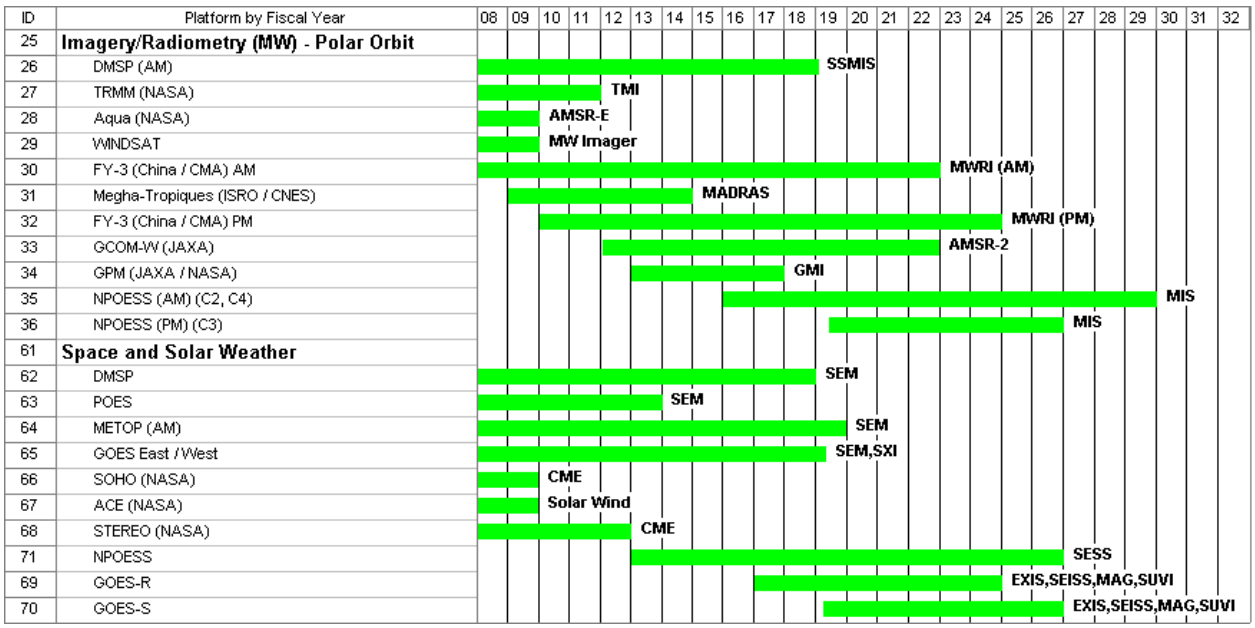

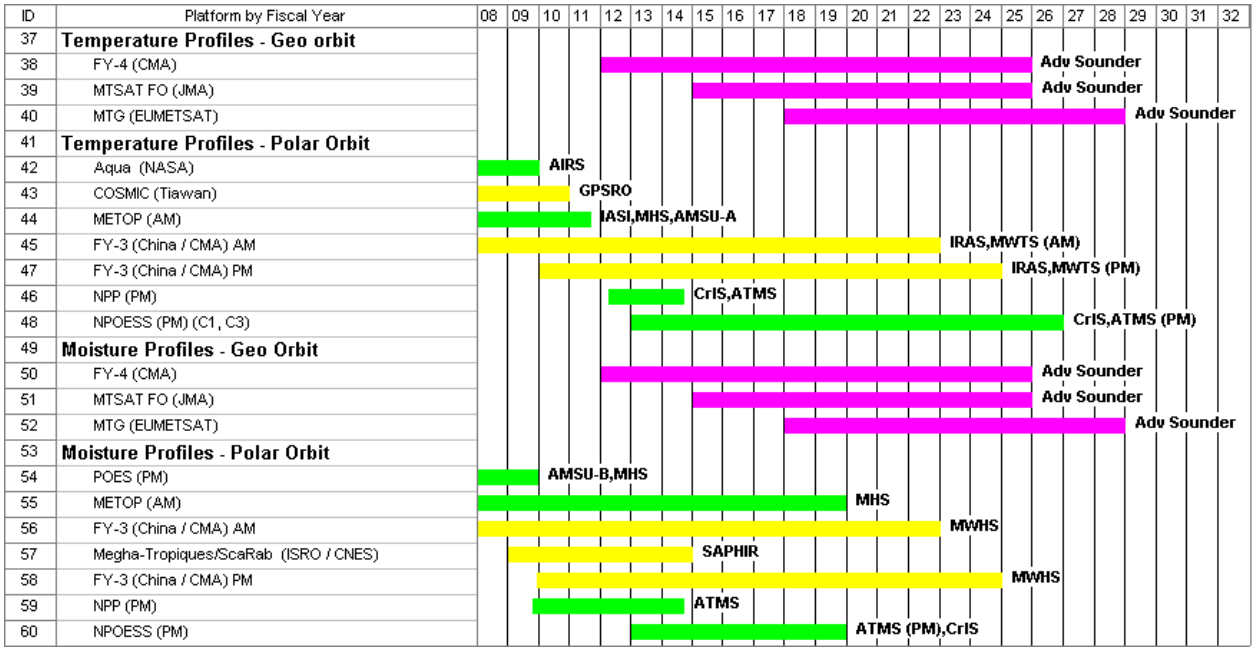

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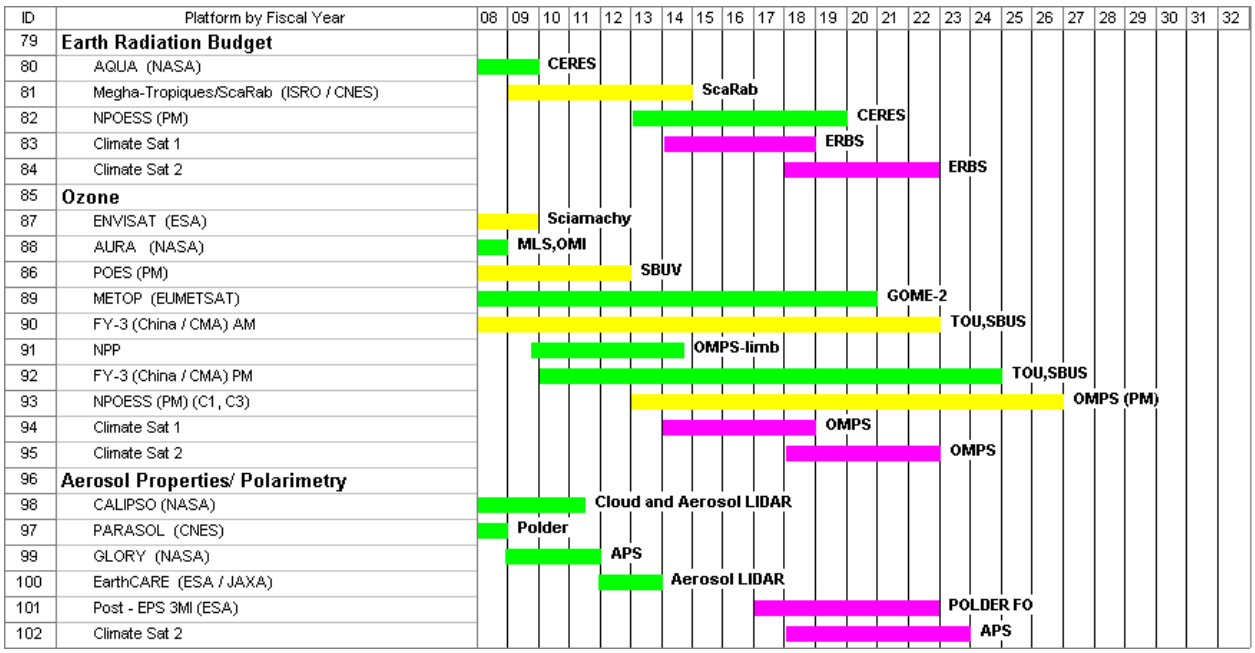

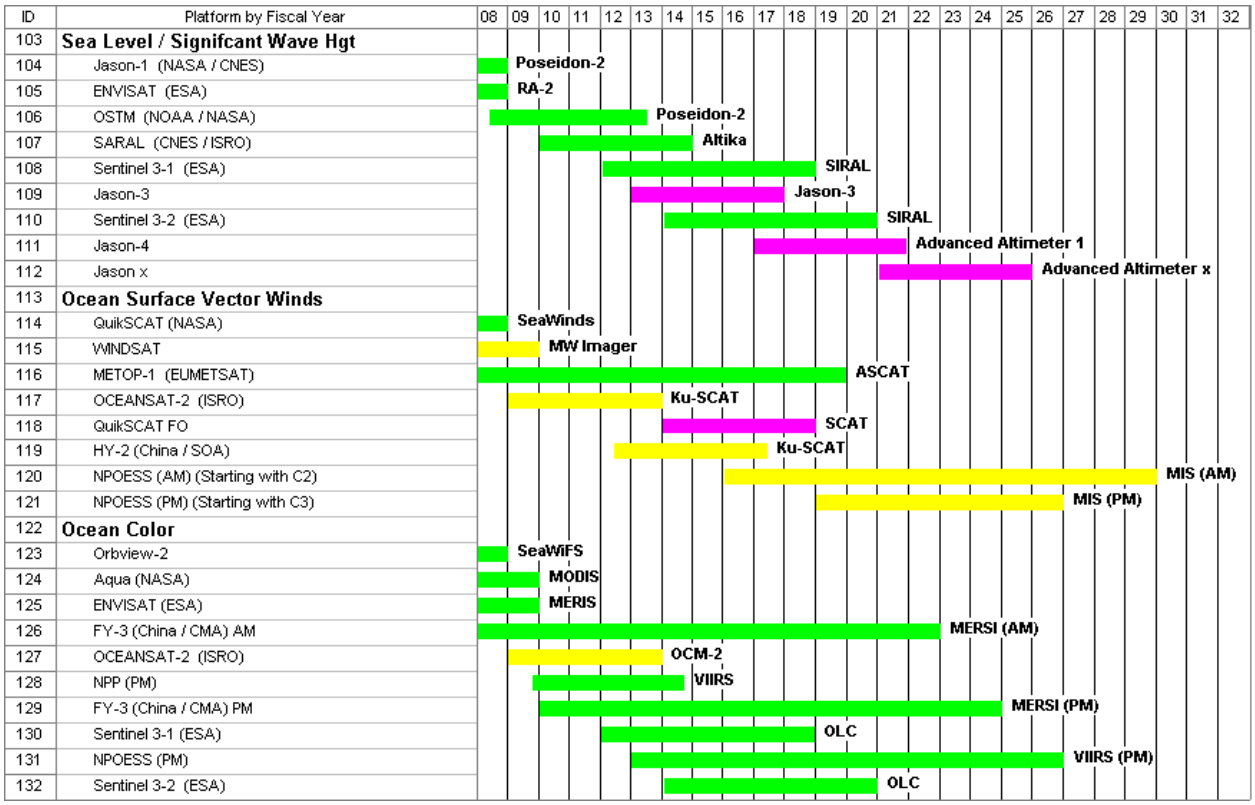

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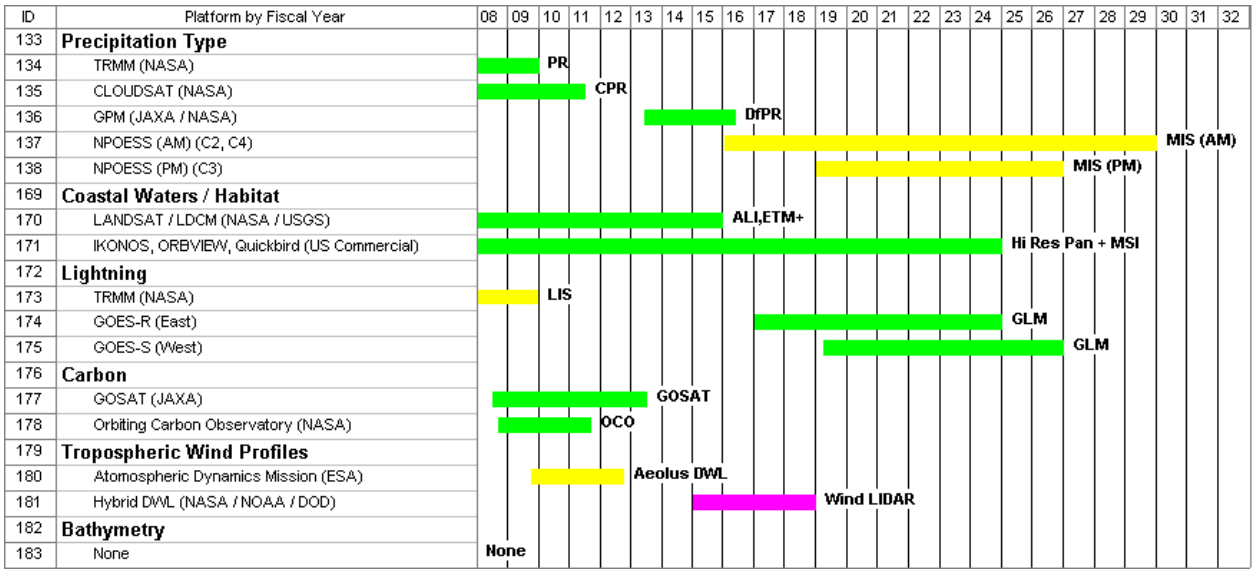
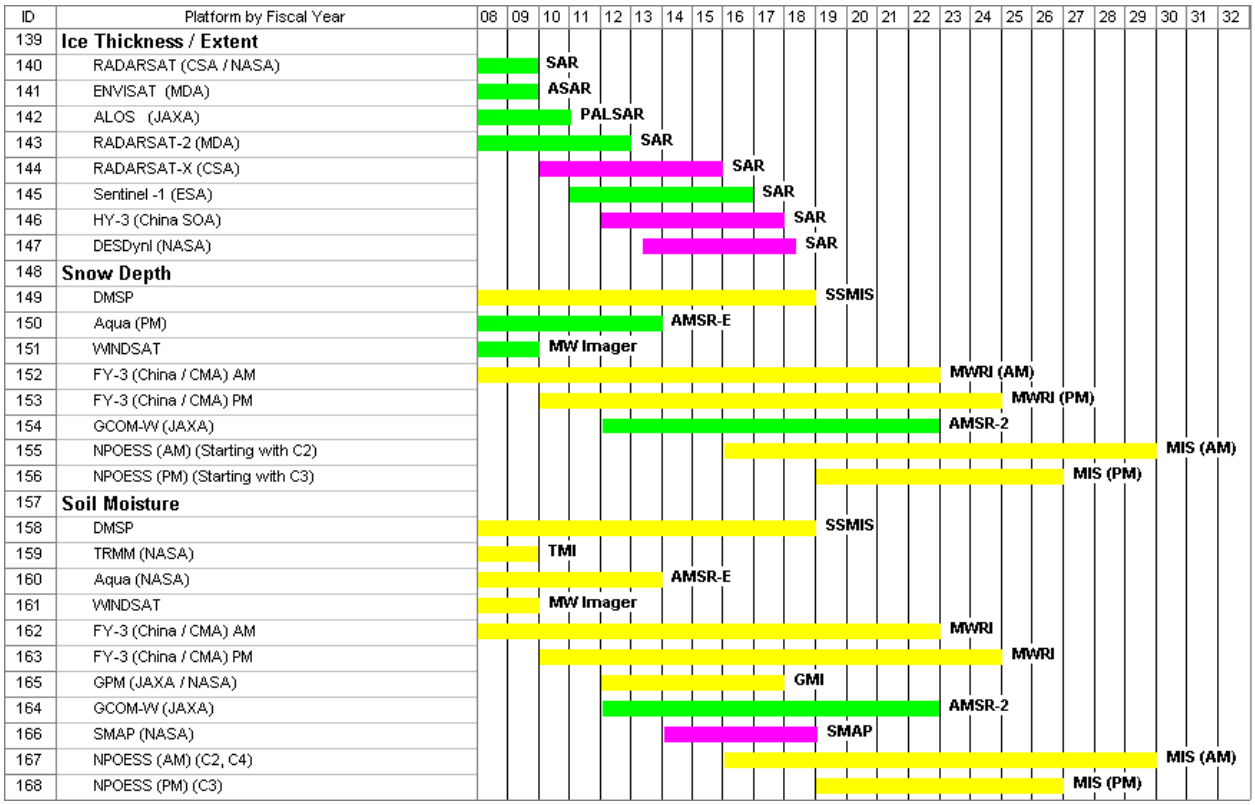
APPENDIX C--REMOTE SENSING SATELLITE FLYOUT CHARTS 2010-2025





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Appendix D NASA Earth Observations Used Operationally by NOAA

Important value-added information is available today from a variety of satellite sources external to NOAA. The largest supplier of non-NOAA data is NASA. Shown below are the satellites, sensors, and measurements/products applied by NOAA (as available) to operational products provided to users. The table describes the NASA satellite name, sensor, product or measurement, a short description of the (NOAA) operational utility and the expected end of life for the satellite or sensor. This information was critical in outlining potential gaps and possible alternatives to NOAA's operational suite of satellite measurements.

Satellite	Sensor	Product(s)	NOAA User Organization(s)	Operational Use Description	Planned End of Life
SORCE	SOLSTICE	Mg II Index	SEC	Operational space weather users of SORCE Mg II index data automatically check the SORCE ftp site for updated data files twice a day to get the latest observations.	2009
Terra & Aqua	MODIS	Radiances, cloud mask, water vapor and ozone profiles, aerosols, cloud products, snow cover, sea ice, ocean color, SST, fire detection	NWS/NCEP NWS/WFOs NESDIS AOML	MODIS polar winds assimilated into operational weather prediction systems, aerosol products used in Volcanic Ash Advisory Center; Coastwatch program uses chlorophyll products; Land surface/sea surface temp/cloud and fog products used for short-term weather forecasts	2009
Aqua	AMSR-E	SST, precipitation rate, integrated atmospheric water quantities	AOML/NHC NCEP NESDISWFOs	Hurricane monitoring and forecasting Coastwatch Program; precipitation and SST used for coastal weather forecasts	2009
Aqua	AIRS	Radiances	NCEP NESDIS NWS/WFOs AOML ESRL	Radiances are assimilated into ECMWF SO2 data used by the Volcanic Ash Advisory Center to issue airline alerts; vertical profiles used to estimate atmospheric stability by weather forecast offices	2009
TRMM	PR/TMI/VIRS	TMI radiances, multi-sensor rainfall products	AOML/NHC NCEP	Monitoring of tropical cyclone, location and intensity; TMI radiances assimilated into numerical weather prediction models; precipitation products used in multi-satellite rain estimates and to estimate flooding potential during hurricanes.	2009

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APPENDIX D--NASA EARTH OBSERVATIONS USED OPERATIONALLY BY NOAA

Satellite	Sensor	Product(s)	NOAA User Organization(s)	Operational Use Description	Planned End of Life
TRMM	LIS	Lightning events	NCEP Aviation Weather Center NWS/WFOs	AWC forecasters overlay conventional vis and ir data with LIS data to improve forecasts of which convective cells have increased likelihood of turbulence, feeds the SIGMET aviation service, used for severe storm warnings	2009
QuikSCAT	SeaWinds	Ocean surface wind speed and directions, backscatter cross-sections	AOML/NHC NESDIS NCEP WFOs NSIDC	Short term prediction of hurricane intensity, path; OSCAR Project for operational surface velocity fields; Weather prediction; Sea ice extent mapping and iceberg tracking; Coastwatch program uses sea surface winds for shipping/navigation advisories.	2008
Jason	JMR/Poseidon-2/DORIS/TRSR	Surface height data	AOML/NHC NESDIS PMEL	Seasonal and short term prediction of hurricane activity, intensity and path; ENSO forecasts, OSCAR Project; Surface current forecasts for shipping, fisheries	2008
Aura	OMI	SO2, near real time ozone product, NO2	NESDIS NCEP	SO2 data used by Volcanic Ash Advisory Center to issue airline alerts; testing ozone data to refine weather forecast; testing OMI NO2 product for air quality forecast.	2008
STEREO	All Sensors	Solar wind parameters, energetic particle flux, coronal mass ejection images	NWS/NCEP/SEC	STEREO coronagraph data and images of the space between the Sun and Earth will be used by SEC to improve the prediction of geomagnetic storms and solar radiation storms STEREO's measurements of the solar wind, energetic particles, and magnetic field at wide separation angles from the Earth will allow long lead-time alerts.	2012
ACE	All Sensors	Solar wind para-meters, energetic particle flux	NWS/NCEP/SEC	ACE data are critical to determine the near-term level of geomagnetic activity and to drive numerous predictive models of the magnetosphere-ionosphere-atmosphere system.	2009 Extended life to 2019

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Appendix E Measurement Area Information

The NOAA Satellite Team reviewed in detail 800 mission critical requirements from the more than 6000 requirements in the operational NOAA Consolidated Observation Requirements List (CORL) to determine the most important satellite measurement areas (23) listed below. Each of these measurements areas are defined by a short overview, the orbit observed today or needed, the current or future missions conduct(ing) the measurement collection, sensor name(s), the impact(s) if not collected, alternatives to current operational collector, and the benefits (societal) derived from this measure.

Measurement Area 1: Imagery/Radiometry (Vis/IR)	
Overview Provides visual imagery of cloud cover, surface delineation, and clear sky sea surface temperature. **Orbit:** Polar + GEO **Missions:** NPOESS/MetOp and GOES-R **Sensors:** Imager (AVHRR MetOp) and Advanced Baseline Imager	**Impact** ➢ Improved ability to characterize snow packs, inc. snow water equivalent, snow depth; less accurate water runoff forecasts and reservoir capacity ➢ Less accurate atmospheric column water, cloud liquid water, etc.; Increased NWP forecast skill ➢ Upgraded weather forecasts and precipitation type identification, decreased forecast skill ➢ Discontinuous satellite data measurements; decreased climate trend identification and accuracy **Alternatives** ➢ Continue data share partnership with ESA ➢ Provide improved sensor (VIIRS like) to cover mid-AM orbit **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Energy Management, Agriculture, Public Health

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Measurement Area 2: Imagery/Radiometry (MW)	
Overview Provides time-series measurements of column-integrated amount of water vapor and liquid water **Orbit:** Polar **Missions:** NPOESS **Sensors:** Microwave Imager/ Sounder	**Impact** ➢ Improved ability to characterize snow packs, inc. snow water equivalent, snow depth; less accurate water runoff forecasts and reservoir capacity ➢ Less accurate atmospheric column water, cloud liquid water, etc.; Increased NWP forecast skill ➢ Upgraded weather forecasts and precipitation type identification, decreased forecast skill ➢ Discontinuous satellite data measurements; decreased climate trend identification and accuracy **Alternatives** ➢ Continue data share partnership with DMSP ➢ No plan to continue data following DMSP fly-out **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Energy Management, Agriculture, Public Health

Measurement Area 3: Atmospheric Temperature Profiles	
Overview Provides measurements of distinct layers in the atmosphere where the temperature either increases, decreases or remains constant with height. **Orbit:** Polar + GEO **Missions:** GOES-T and NPOESS **Sensors:** Advanced Sounder (GOES), CrIS/ATMS (NPOESS)	**Impact** ➢ High-frequency temperature soundings improve mesoscale weather predictions **Alternatives** ➢ Develop Advanced Sounder for GOES-T+ ➢ Continue lesser quality sounding in GEO with ABI **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Public Health, Disaster Management

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Measurement Area 4: Atmospheric Moisture Profiles	
Overview Provides measurements of the moisture content of the air as indicated by specific humidity, dew point, vapor pressure, water vapor mixing ratio, and water vapor density. **Orbit:** Polar + GEO **Missions:** GOES-T and NPOESS **Sensors:** Advanced Sounder (GOES), CrIS/ATMS (NPOESS)	**Impact** ➢ High-frequency moisture sounding improve mesoscale weather predictions **Alternatives** ➢ Develop Advanced Sounder for GOES-T+ ➢ Develop GEO MW Sounder **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Public Health, Disaster Management

Measurement Area 5: Precipitation Type	
Overview Determination of types of precipitation such as rain, drizzle, freezing rain, freezing drizzle, hail, or sleet **Orbit:** Polar Missions: TRMM, GPM, NOAA Precip Radar Mission **Sensors:** Precipitation Radar	**Impact** ➢ Ability to provide all-weather information about the hydrological cycle such as latent heat release and the affect on storm dynamics, circulation and atmospheric structure ➢ Ability to determine storm characteristics; reduces severe weather and regional forecast uncertainty ➢ Ability to assess mesoscale system characteristics; increased regional forecast accuracy **Alternatives** ➢ NASA Global Precipitation Mission (GPM) Operational Utilization ➢ NOAA Operational GPM Precipitation Radar Development **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Public Health, Agriculture

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Measurement Area 6: Lightning	
Overview Capability to continuously count and map lightning discharges during both day and night. **Orbit:** GEO **Missions:** GOES-R **Sensors:** Lightning Mapper	**Impact** ➢ Severe Weather indicator (cloud-to-cloud and intra-cloud lightning strikes) ➢ Capability to continuously count and map lightning discharges during both day and night. ➢ Ability to measure Tropical Storm intensity *Enhances current non-satellite ground systems **Alternatives** ➢ New Start **Benefits** Weather Forecasting, Water Management, Disaster Management, Public Health

Measurement Area 7: Soil Moisture	
Overview Determines water content in the soil **Orbit:** Polar **Missions:** NPOESS, DMSP **Instrument:** Microwave Imager/Sounder	**Impact** Improvement to water, energy, and carbon management efficiencies ➢ Increased uncertainty in Flood prediction ➢ Increased ability to assess ground moisture/saturation state ➢ Improved irrigation plans **Alternatives** ➢ NPOESS Microwave Imager/Sounder ➢ Soil Moisture Active Passive (SMAP) NASA option operational evaluation **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Disaster Management, Public Health, Agriculture

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Measurement Area 8: Ocean Surface Vector Winds	
Overview Near real-time measurements of ocean surface vector winds (OSVW), including both wind speed and direction. **Orbit:** Polar **Missions:** QuikSCAT **Instrument:** Scatterometer	**Impact** ➢ Upgrades hurricane model initial analysis leading to increased intensity and forecast accuracy ➢ Upgrades mesoscale model initial analysis; Increases forecast skill **Alternatives** ➢ Develop scatterometry mission with NASA, QUIKSCAT follow-on ➢ Utilize MetOp data in the interim at a reduced capability **Benefits** Ecology, Disaster Management, Weather Forecasting, Public Health, Ocean Management

Measurement Area 9: Sea Surface Height	
Overview The height (or "relief") of the sea surface is caused by both gravity and the active ocean circulation. **Orbit:** Polar **Missions:** JASON, OSTM **Instrument:** Altimeter	**Impact** ➢ Ability to provide accurate ocean specification for numerical ocean models, Increased ocean prediction accuracy, and ocean circulation models ➢ Upgraded capacity for predicting hurricane intensity/ocean heat potential; increased hurricane intensity and forecast accuracy ➢ Continued sea level/height satellite record; climate trend identification and accuracy **Alternatives** ➢ Develop Jason FO, partnering with NASA, CNES, EUMETSAT ➢ International partnership for data buy from SARAL, Sentinel series **Benefits** Climate Variability and Change, Ecology, Ocean Management, Disaster Management, Public Health

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Measurement Area 10: Ocean Color	
Overview Phytoplankton contain chlorophyll, which absorbs red and blue light and reflects green light. Particles can reflect and absorb light, which reduces the clarity (light transmission) of the water. Dissolved organic matter strongly absorbs blue light, and its presence can interfere with measurements of chlorophyll. **Orbit:** Polar **Missions:** NPP/NPOESS **Instrument:** VIS/IR Radiometer	**Impact** ➢ Ability to characterize the amount of live biomass (e.g. phytoplankton), turbidity, identify algal blooms, and track plumes ➢ Slow develop a seasonal assessment of chlorophyll and turbidity within the contiguous United States coastal zone **Alternatives** ➢ Continue as planned on NPOESS using the VIIRS **Benefits** Public Health, Disaster Management, Ecology, Ocean Management

Measurement Area 11: Coastal Waters/Ocean Habitats	
Overview High-resolution imagery for base maps and wetland guidance maps allowing users to discern land use or land cover **Orbit:** Polar, GEO **Missions:** NPP/NPOESS **Instrument:** VIS/IR Radiometer	**Impact** Provides satellite observations for modeling & forecasting capabilities for ecological and biogeochemical processes in coastal ecosystem management ➢ Ability to effectively monitor ecosystem change; increased capability to identify key trends or mitigating actions ➢ Increased ability to quantify measurements; increased habitat prediction system uncertainty **Alternatives** ➢ Continue data buy with SPOT (CNES), QuickBird (DigitalGlobe), and Ikonos (Space Imaging) ➢ Data share with Ocean sat 2 (ISRO) and Sentinel 3 (ESA) **Benefits** Public Health, Disaster Management, Ecology, Ocean Management

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Measurement Area 12: Bathymetry	
Overview Measurement of water depth, i.e., ocean bottom topography **Orbit:** Polar **Missions:** TBD **Instrument:** Altimeter	**Impact** ➢ Ability to calculate ocean bottom topography ➢ Increases navigation chart accuracy and ocean model predications ➢ Increases accuracy in Tsunami predictions ➢ Upgraded ability to forecast safe maritime passage **Alternatives** ➢ Develop non-sun sync, no-repeat orbit altimeter mission with NASA ➢ Develop Surface Water, Ocean Topography (Decadal Survey recommendation) **Benefits** Public Health, Disaster Management, Ocean Management, Ecology, Climate Variability and Change

Measurement Area 13: Earth Radiation Budget	
Overview Measures balance between incoming energy from the sun and the outgoing longwave (thermal) and reflected shortwave energy from the Earth. **Orbit:** Polar **Missions:** NPP/NPOESS **Instrument:** Radiant Energy System	**Impact** Improvement to global climate change predictions ➢ Continuous satellite record of incoming and outgoing radiation; increased energy balance accuracy and climate trend identification ➢ Upgraded capability for global and mesoscale energy balance; increases mesoscale forecast accuracy and climate trend accuracy **Alternatives** ➢ Re-manifest to NPOESS C1 and C3 ➢ Develop CERES satellite follow-on mission program with NASA **Benefits** Climate Variability and Change, Weather Forecasting, Public Health, Disaster Management, Ecology, Ocean Management

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Measurement Area 14: Aerosols	
Overview Measures dispersion of solid and liquid particles suspended in gas. **Orbit:** Polar **Missions:** TBD **Instrument:** Polarimeter	**Impact** Improvement to global climate change predictions ➢ Improved accuracy of aerosol optical depth; increased forecast accuracies of visibility, pollution impacts, etc. ➢ Ability to get aerosol type and size distribution; Increases accuracy of regional predictions **Alternatives** ➢ Re-manifest polarimeter instrument to NPOESS ➢ Develop Climate Satellite with NASA that measures multiple climate variables **Benefits** Climate Variability and Change, Ecology, Public Health

Measurement Area 15: Ozone Profile	
Overview Provides measurements of distinct layers in the atmosphere and troposphere where ozone either increases or decreases with height **Orbit:** Polar **Missions:** NPP/NPOESS **Instrument:** Ozone Mapper/Profiler	**Impact** ➢ Ability to measure ozone profile to compliment the Total Ozone measurement, leading to a increase in the ability to track ozone change and make predictions for public safety ➢ Increased ability to distribute energy vertically in atmosphere; increases forecast skill **Alternatives** ➢ Re-manifest limb capability to NPOESS ➢ Continue data share with MetOp GOME **Benefits** Agricultural, Ecology, Climate Variability and Change, Public Health

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Measurement Area 16: Solar Irradiance	
Overview Measure of the rate of solar energy arriving at the Earth's surface from the Sun's direct beam, on a plane perpendicular to the beam. **Orbit:** Polar **Missions:** TBD **Instrument:** Irradiance Monitor	**Impact** ➢ Continuous satellite record of solar constant observations leading to increased energy balance accuracy and related climate trend identification ➢ Improved capability to determine the global energy balance, Increases regional prediction accuracy **Alternatives** ➢ Re-manifest polarimeter instrument to NPOESS ➢ Develop Climate Satellite with NASA that measures multiple climate variables **Benefits** Climate Variability and Change, Weather Forecasting, Public Health, Disaster Management, Ecology, Ocean Management

Measurement Area 17: Carbon	
Overview Measure carbon dioxide (CO2) data to improve our understanding of the natural processes and human activities that regulate the abundance and distribution of this important greenhouse gas. **Orbit:** Polar **Missions:** TBD **Instrument:** Spectrometer	**Impact** Ability to quantify carbon sources and sinks ➢ Upgrades capability to predict regional ecosystem impacts ➢ Upgrades capacity for understanding carbon climate trends ➢ Increases forecast accuracy for effluents and their impact **Alternatives** ➢ Develop Climate Satellite with NASA that measures multiple climate variables ➢ Develop carbon sensor free flyer, i.e. OCO follow-on **Benefits** Ecology, Climate Variability and Change, Public Health

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Measurement Area 18: Snow Depth	
Overview Depth of snow is the vertical interval between the top surface of a snow layer and the ground beneath. **Orbit:** Polar +/or GEO **Missions:** TBD **Instrument:** Microwave Radiometer	**Impact** Increased prediction capability for water supplies, floods, weather, and climate ➢ Ability to quantify snow depth; impacts flood and run-off prediction accuracy ➢ Improved albedo/extent specifications; reduces albedo and temperature forecast uncertainty **Alternatives** ➢ Data share or buy from China through 2020 ➢ Develop snow depth instrument **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Ocean Management

Measurement Area 19: Ice Thickness	
Overview Determines ice surface elevation and ice thickness **Orbit:** Polar +/or GEO **Missions:** TBD **Instrument:** Synthetic Aperture Radar	**Impact** Increased ability to estimate the effects of increasing greenhouse gases on the future global climate ➢ Ability to assess ice characteristics ➢ Improved forecast skill for maritime passage ➢ Upgraded climate trend predictions **Alternatives** ➢ Continue data buy from Canada for RadarSat data ➢ Partner with NASA for the DESDynI Mission (Decadal Survey recommendation) **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Ocean Management

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Measurement Area 20: Tropospheric Winds	
Overview Determines atmospheric wind speed and direction data above cloud/surface (clear sky) **Orbit:** Polar **Missions:** ADM (ESA); Hybrid Doppler Wind LIDAR **Sensors:** Aeolus (ESA); Doppler Wind LIDAR (NASA/NOAA)	**Impact** ➢ Improved weather (including over ocean) forecast and long-term analysis of systems (including severe storm) development over oceans **Alternatives** ➢ Operationally evaluate ADM/Aeolus data for utility ➢ Technology pull with NASA to jointly pursue Hybrid Doppler Wind LIDAR **Benefits** Ecology, Disaster Management, Public Health, Climate Variability and Change, Weather Forecasting

Measurement Area 21: Radio Occultation	
Overview Indirect measurement of temperature, pressure and water vapor in the stratosphere and the troposphere **Orbit:** Any (Polar Preferred) **Missions:** COSMIC (Data Buy), MetOp **Sensors:** GPS Radio Occultation, GRAS (Refractive Index)	**Impact** Calibration improvements, since GPSRO observations are totally independent of other atmospheric observations and are very precise ➢ Ability to accurately specify temp and moisture profiles near tropopause and stratosphere; Upgrades global and regional model skill ➢ Ability to measure electron density profiles; Increases communications forecast accuracy **Alternatives** ➢ Radio Occultation mission follow-on ➢ Partial Capability MetOp (GRAS) after 2012 **Benefits** Climate Variability and Change, Weather Forecasting, Water Management, Energy Management, Public Health, Disaster Management

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Measurement Area 22: Space Environment	
Overview Determine solar weather conditions including solar atmospheric conditions, solar flares, and geomagnetic storms **Orbit:** Anywhere Solar Visibility **Missions:** GOES Series **Instrument:** Solar UV Imager, X-ray Sensor	**Impact** Increased ability to predict geomagnetic storms ➢ Solar and coronal mass ejections can disable satellites and disrupt communication signals ➢ Ability to improve solar warning time for communication/intel satellites, astronaut safety, and polar airline flight safety ➢ Ability to measure solar wind upstream of the Earth; Increased forecast accuracy of communications forecasts, magnetic storm predictions, scintillation predictions and hazards to personnel in space **Alternatives** ➢ Develop coronal mass ejection (CME) imager **Benefits** Public Health, Energy Management, Climate Variability and Change

Measurement Area 23: Solar Measurements	
Overview Measurement of a stream of charged particles (i.e., plasma) which are ejected from the upper atmosphere of the sun. It consists mostly of high-energy electrons and protons that are able to escape the sun's gravity in part because of the high temperature of the corona and the high kinetic energy that particles gain. **Orbit:** L1 **Missions:** Operational Solar Wind **Instrument:** Magnetometer, Plasma Sensor, Particle Sensor	**Impact** Increased ability to predict geomagnetic storms ➢ Solar and coronal mass ejections can disable satellites and disrupt communication signals ➢ Ability to improve solar warning time for communication/intel satellites, astronaut safety, and polar airline flight safety ➢ Ability to measure solar wind upstream of the Earth to increase accuracy of communications forecasts, magnetic storm predictions, scintillation predictions, and hazards to personnel in space **Alternatives** ➢ Develop solar wind mission program at the L1 libration point **Benefits** Public Health, Energy Management, Climate Variability and Change

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Appendix F Socioeconomic Tables

The societal benefits are derived from the U.S. Integrated Earth Observation System Strategic Plan (2005). These benefits are defined below:

- ***Improve Weather Forecasting:*** Enhanced observations would greatly facilitate the weather mission in the U.S., as well as supply crosscutting information for the user requirements in the other societal benefit areas.
- ***Reduce Loss of Life and Property from Disasters:*** Natural hazards such as earthquakes, volcanoes, landslides, floods, wildfires, extreme weather, coastal hazards, sea ice and space weather, plus major pollution events, impose a large burden on society. Disasters are a major cause of loss of life and property. Our ability to predict, monitor, and respond to natural and technological hazards is a key consideration in reducing the impact of disasters.
- ***Protect and Monitor Our Ocean Resource:*** Our ability to observe and manage coastal and marine resources will continue to provide these key benefits to society. Managing ocean resources requires accurate information from an integrated observation system to allow for detection and prediction of the causes and consequences of changes in marine and coastal ecosystems, watersheds and non-living resources.
- ***Understand, Assess, Predict, Mitigate, and Adapt to Climate Variability and Change:*** The Earth's climate is a dynamic system undergoing continuous change on seasonal, annual, decadal and longer timescales. Better preparation for any impacts due to climate variability and change requires better understanding of its causes and effects.
- ***Understand the Effect of Environmental Factors on Human Health and Well-Being:*** All the components of this integrated Earth observation system contribute to improving human health and well-being. Researchers, service providers, policy makers, and the public currently use Earth observations to understand environmental factors in order to make decisions and take actions.
- ***Protect and Monitor Water Resources:*** The availability and quality of freshwater for humans are critical factors influencing the health and livelihood of people across the nation. By providing more complete and detailed water information and forecasts, decision-makers and the public could make better decisions on water supplies and activities that affect humans, plants, animals, and ecosystems.
- ***Develop the Capacity to Make Ecological Forecasts:*** The primary goal of ecological forecasting is to predict the effects of biological, chemical, physical, and human induced pressures on ecosystems and their components at a range of scales and over time, given a certain set of assumptions. Earth observations and relevant modeling tools help identify key cause-effect relationships.
- ***Support Sustainable Agriculture and Forestry, and Combat Land Degradation:*** Food production is a national priority and it is characterized by fluctuations related to climate conditions, land management practices, agricultural technologies, market forces, and investment. Seasonal and longer-term trends of temperature and rainfall patterns are a great influence on agricultural, desert and range, and forestry sectors.

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- ***Monitor and Manage Energy Resources:*** Energy management and monitoring are compelling needs throughout the world. Energy availability, use, and cost vary regionally. Focused efforts with improved Earth observations can help to optimize decision-making, and help provide needed energy supply, while protecting the environment and human health.

NOAA Satellite Payoffs*

- Support and sustain Agricultural and Forest
  - Return on investment for every dollar spent on forecasting: $15
  - Global Benefits from improved El Nino/La Nina forecasts: > $450 to 550M/year
- Understand, Assess, Predict, Mitigate, and adapt to Climate Variability and Change
  - Global damage due to rising temperatures impacts ~ 1.5-2% of the GNP
  - In the U.S., about 1/3 of the GDP is climate/weather sensitive: $3T is at risk in agriculture, finance, insurance, and real estate, retail and wholesale trade, and manufacturing
  - In pure economic terms, studies show that national institutions providing weather, climate, and water services to their citizens contribute an estimated $20-$40B/year to their national economies
- Reduce Loss of Life and Property from Disasters
  - Increase in warning lead-times decreases deaths & injuries, and provides substantial monetary savings (up to $30M/year)
  - Reduce loss of satellites due to geomagnetic storms: $500+M/per incident
- Monitor and Management of Energy Resources
  - Reduce electricity cost by at least $1B with improved/accurate weather forecasts by just one degree
- Improve Weather Forecasting
  - Improved Hurricane Forecast: Reduce unnecessary evacuations (up to $1M/mile)
  - Increase accuracy in weather numerical models and forecasts (>$137M/year)
  - Reduce aviation icing event: up to $243M/year

NOAA Satellite Impacts

- Support and sustain Agricultural and Forest
  - A 1° C SST increases in the equatorial Pacific in August results in a fall in the Indonesian rice harvest of more than 1 million metric tons, and world rice prices rise about 10%*
  - Improve crop management and yields (pesticide need, crop irrigation, earliest planting date)

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* EOM Magazine, August/September 2003

NASA Societal Benefits of Ocean Altimetry Data, 2002

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Miller, "Societal Benefits of Winds Mission", Mitretek Systems, 2007

Cordes, "Economic Benefits and Costs of Developing and Deployig A Space Based Wind Lidar," GWU, NOAA Contract, 1995

Air Transport Association, Average Airline Paid Price and Consumption, 2006

Cordes, "Memorandum to W Baker, "Projected Benefits in Miliatry Fuel Savings from Lidar," 1998

Rayner, "Prediction and Other Approaches to Climate Change Policy", 2000

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- Improve wild fire management and probability

- Understand, Assess, Predict, Mitigate, and adapt to Climate Variability and Change
  - Improve early detection of anti-cyclonic development (ocean color)
  - Continue monitoring patterns of rising sea levels, ocean warming, evaporation (Global ocean picture)
- Monitor and Management of Energy Resources
  - Optimize flight patterns
  - Reduce fuel usage
  - Reduce wait time on runways
- Monitor and Management of Environmental Factors affecting Human Health
  - Reduce the overall cost of oil pollution incidents by improved deployment of oil-spill clean-up equipment
  - Avoid sudden volcanic plumes (aviation)
- Protect and Monitor Our Ocean Resource
  - With more accurate forecasts, ships at sea can make route corrections to take advantage of favorable weather and currents and avoid hazardous weather sooner, thus saving time and money
- Develop Ecological Forecasting
  - Improve fisheries management, track harmful debris, ship routing using improved mapping of currents/eddies
  - Improve marine animal tracking

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Capability/ Continuity Gap	Socioeconomic Impact	Risk (If not mitigated)	Comments
Sea Surface Height (CL, ECO, WW, CT)	• Continue monitoring Global Sea Level Rise • Increase Hurricane Forecast Accuracy--Improve capacity to predict hurricane intensity/ocean heat potential •Reduce Unnecessary Evacuations (up to $1M/mile*) • Increase Flood Mapping Accuracy for coastal regions	High	Potential discontinuity after OSTM
Tropospheric Wind Profiles (CL, WW)	• Increase accuracy in weather numerical models and forecasts (>$137M/year**) • Reduced Hurricane Over-warnings (up to $1M/mile*) • Reduce preventable damage & business interruptions (up to $30M/year***) • Save aviation fuel usage (com'l savings $243M*** / military savings $101M****)	High	No System with available technology; New Capability
Solar Irradiance (CL, ECO, WW)	• Continue satellite records of climate observations (including solar irradiance and carbon) for climate change decision makers • Improve predictions for climate pattern changes • Improve predictions for global precipitation and global air temperature changes • Global damage due to rising temperatures impacts approximately 1.5-2% of the GNP***** • Continue capability to determine the global energy balance, reduces regional prediction accuracy	High	Discontinuity after GLORY Mission (2011)
Carbon (CL, ECO)		High	No continuity following OCO after 2016

Capability/ Continuity Gap	Impact/Consequence	Risk (If not mitigated)	Comments
Radio Occultation (CL, ECO, WW, CT)	• Accurate temperature and moisture profiles near tropopause/stratosphere (global and regional) • measure electron density profiles	Moderate	Partial capability with MetOp/GRAS after 2012
Space & Solar Weather at L1 (WW, CT)	• Early Warning System Improvement •Energy Management •Satellites •Communication (i.e. High Frequency Radio, Navigation, Intelligence/reconnaissance) • Human Health •Biological Exposure (International Space Station, Polar routed airline passengers) •Search and Rescue comm-link interference with NOAA satelltes	Moderate	Reduced capability after ACE and DMSP (2019)
Soil Moisture (CL, WW, CT)	• Water Resource Management •Forest Fires •Flood/Drought Monitoring (Early Warning System for Floods) • Agriculture •Irrigation Requirements •Yield Forecast Management (i.e. pesticides) •Sediment Transport • Human Health • 1-2 day Weather Forecast improvements	Moderate	DMSP SSMIS & NOAA MIS may provide partial capability
Ice Thickness (CL, ECO, WW, CT)	• Climate •Ocean energy exchange •Earth's Energy Balance	Low	No System with available technology; New Capability
Snow Depth (CL, WW, CT)	• Water Resource Management •Forest Fires •Early Warning System for Floods • Climate •Ocean energy exchange •Earth's Energy Balance	Low	No System with available technology; New Capability

Capability/ Continuity Gap	Impact/Consequence	Risk (If not mitigated)	Comments
Solar Irradiance (CL, ECO, WW)	• Continue satellite records of climate observations for climate change decision makers •Improve predictions for climate pattern changes •Improve predictions for global precipitation and global air temperature changes •Global damage due to rising temperatures impacts approximately 1.5-2% of the GNP***** •Continue capability to determine the global energy balance, reduces regional prediction accuracy • Ecosystems •Aquatic plants/animals •Plankton • Agriculture •Crop yields •Chemical usage • Atmospheric transport •human activity (i.e. burning of fossil fuel) •Effects of natural occurrences (i.e. volcanic eruption) •Improved Air Quality Modeling with better understanding of pollution export from large cities •Effects on Human Health (i.e. skin cancer, skin aging, eye damage) •Pollution-related tropospheric ozone and aerosols	High	Discontinuity after GLORY Mission (2011)
Carbon (CL, ECO)		High	No continuity following OCO after 2016
Earth Radiation Budget (CL, ECO, WW, CT)		Moderate	Discontinuity after NOAA CERES (2020)
Ozone-Profile (CL, WW)		Moderate	Discontinuity after NPP (2014)
Aerosol/Polarimetry (CL, ECO, WW, CT)		Moderate	Discontinuity after GLORY Mission (2011)

Capability/ Continuity Gap	Impact/Consequence	Risk (If not mitigated)	Comments
Sea Surface Height (CL, ECO, WW, CT)	•Climate •Continue monitoring patterns o rising sea levels, ocean warming, and evaporation (Global Picture ocean systems) •Ocean Color imagery (altimeter/scatterometer) (early cyclonic development) •Costal Geostrophic Surface Mapping (altimeter/radiometer0 •Coastal Mesoscale Circulation •Trace element iron in the ocean and carbon uptake •Hurricane forecast (warm water Loop currents of the Gulf, storm surge, high dynamic topography) •Reduce Unnecessary Evacuations (up to $1M/mile*) •Long-term seasonal forecasts •El Nino/La Nina Forecast •Marine Operations and Research •Increase Flood Mapping Accuracy for coastal regions •Maps of Currents/Eddies (fisheries management, debris tracking, ship routing, cyclonic development) •High wind profiles (air/sea surface flux) •Ocean Circulation/Strong currents (Offshore Industries) •Marine Mammal research (eddies where nutrients and plankton are abundant, Stellar sea lions, sea Turtles, tuna) •Coral Reef Ecosystems sensitive to large-scale climate variability •Land Operations •Inland Waters (Flood/Drought) •Ice Sheet Elevation •Other •Insurance (cargo loss at sea) •Tsunami coastal warning	High	Potential discontinuity after OSTM
Ocean Surface Vector Winds (CL, ECO, WW, CT)		High	ASCAT & NOAA MIS provide partial capability
Coastal Water/Habitat (CL, ECO, WW)		Moderate	No System with available resolution/cover age; New Capability
Bathymetry (CL, ECO, WW, CT)		Low	Potential capability with non-sun sync orbit

Capability/ Continuity Gap	Impact/Consequence	Risk	Comments
Tropospheric Wind Profiles (CL, WW)	• Increase accuracy in weather numerical models and forecasts (>$137M/year**) •Reduced Hurricane Over-warnings (up to $1M/mile*) •Reduce preventable damage & business interruptions (up to $30M/year***) • Agriculture •Crop Management •Irrigation Decisions •Preventative Maintenance (crop disease) • Energy •Planned purchase of gas/electricity •Managed response to emergency situations •Managed capacity/resources • Aviation and other Transportation •Optimized flight patterns •Reduced wait times on runways (public safety) •Avoidance of sudden volcanic plumes •Reduce icing incidents •Reduction in airline accidents (5-6/yr) saving 120Meuro-125 •Fuel Savings 375-1500Meuro •Save aviation fuel usage (com'l savings $243M*** / military savings $101M****) •Improved Transportation Planning (i.e. state transportations dept) •Increased mobility •Reduction in chemical cost •Efficient staffing • Tourism/Recreation •Improving ski slope demand/requirements for artificial snow •Marine Forecast Warnings	High	No System with available technology; New Capability
Precipitation Type (CL, WW, CT)		Low	GPM and follow-on to address capability; New Capability
Conical Microwave and VIS/IR Imagery/Radiometry (CL, WW, CT)		Low	Planned coverage in two orbits (versus 3 planned)

Capability/ Continuity Gap	Impact/Consequence	Risk (If not mitigated)	Comments
Radio Occultation (CL, ECO, WW, CT)	• Accurate temperature and moisture profiles near tropopause/stratosphere (global and regional) • measure electron density profiles	Moderate	Partial capability with MetOp/GRAS after 2012
Space & Solar Weather at L1 (WW, CT)	• Early Warning System Improvement •Energy Management •Satellites •Communication (i.e. High Frequency Radio, Navigation, Intelligence/reconnaissance) • Human Health •Biological Exposure (International Space Station, Polar routed airline passengers) •Search and Rescue comm-link interference with NOAA satelltes	Moderate	Reduced capability after ACE and DMSP (2019)
Soil Moisture (CL, WW, CT)	• Water Resource Management •Forest Fires •Flood/Drought Monitoring (Early Warning System for Floods) • Agriculture •Irrigation Requirements •Yield Forecast Management (i.e. pesticides) •Sediment Transport • Human Health • 1-2 day Weather Forecast improvements	Moderate	DMSP SSMIS & NOAA MIS may provide partial capability
Ice Thickness (CL, ECO, WW, CT)	• Climate •Ocean energy exchange •Earth's Energy Balance	Low	No System with available technology; New Capability
Snow Depth (CL, WW, CT)	• Water Resource Management •Forest Fires •Early Warning System for Floods • Climate •Ocean energy exchange •Earth's Energy Balance	Low	No System with available technology; New Capability

Appendix G NOAA Proposed Satellite Actions

NOAA's Strategic Satellite Plan assumes commitments to the continue the geostationary and polar-orbiting missions capabilities existing today with planned system and sensor improvements. In addition, the current acquisition programs will expand the quantity and quality of satellite observations for improved Numerical Weather Predictions and real-time forecasting.

The Strategic Satellite Plan also assumes a continued partnership with the National Aeronautics and Space Administration (NASA). To reduce acquisition times for major satellite developments, the NASA and NOAA plan to participate in new research missions to demonstrate capabilities that enhance NOAA capabilities, improve research-to-operations transitions, and strive towards improving global weather and climate model predictions. Within the next decade, NASA-NOAA partnership programs should include NASA mission already in the planning stages [i.e. the Orbiting Carbon Observatory (OCO), the Global Precipitation Measurement (GPM), and the Aquarius Ocean Salinity Mission] and new missions like those recommended by the NRC Decadal Survey.

Leveraging international partnerships with key organizations like the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), the Centre National d'Etudes Spatiales (CNES), and the Japan Space Exploration Agency (JAXA) will provide the basis for the Global Earth Observation System of Systems (GEOSS) capability that will benefit many nations. With the continued MetOp Mission and the new Jason Altimetry Mission, NOAA satellite capabilities will provide critical environmental measurements for global meteorological, climate, and ocean models. In addition, data sharing for space weather capability will provide solar environmental measurements and observations of the ionosphere and magnetosphere. Data purchases of synthetic aperture radar data for ice identification and temperature/moisture profiles from COSMIC will continue to be a part of NOAA's balanced approach to strategic satellite planning.

A summary of the proposed satellite program actions contained in this plan follow:

Part I: Proposed Actions for the Projected Satellite Program
Part II: Trade Studies for the Projected Satellite Program

a. Trade decisions <u>above</u> the **heavy black line** require action NLT 2008.
b. Trade decision opportunities for the OIIP partnership with NASA are <u>outlined</u> in **heavy gold box.**
c. * Asterisks in 'Decision Timelines' column <u>means</u> 'Best Estimate for Feasibility Date.'

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Part I: Proposed Actions for the Projected Satellite Program					
Timeline	**Inherent Strategic Actions for NOAA's Satellite Mission**	**If**	**Then**	**Impacts** **Application Impact**	**Technical Ref to Appendix E** **(MA=measure -ment area)**
2008	NOAA continues the geostationary and polar orbiting missions	Yes	Continued support for the NOAA Mission Goal Teams and Programs		
		No	Discontinue geostationary orbit after the GOES R/S and discontinue polar-orbit after NPOESS C4	Other platforms or satellite orbit would be required for all satellite measurements	
2008	The Consolidated Observations Requirements List (CORL is the database for requirements management	Yes	Centralized location for requirements management of satellite requirements to assure that all NOAA needs are evaluated, vetted, and prioritized	Available through NOAA/NESDIS/TPIO All data products	
		No	Accept increased risk to 'stray' requirements, multiple developments of the same data product, and non-optimalized satellite constellation	Multiple data bases without centralized review process	
2008	Partner with NASA in the US Wind Lidar Demonstration Program	Yes	Improved forecasting for weather precipitation amount and coverage, hurricane track, and hurricane intensity Improved Climate Data Records Improved monitoring of the doldrum and jetstreams leading to improved global forecast Economic (U.S.) benefit: >$800M/Year		
		No	NASA may not proceed with a US Lidar Winds Demonstration Mission	**1.** Delay operational US Lidar Mission	
2008	New Start Program for Scatterometry Relates to trade study for: Combined Altimetry/ Scatterometry Mission	Yes	ASCAT (50kM) & MIS (TBD) provide interim partial capability at the end of QuikSCAT (25kM) until QuikSCAT follow-on is operational, meeting requirement for all-weather condition coverage Records	Applications ➢ Sea-surface wind speed & direction data under all weather/cloud conditions ➢ Acquires hundreds of times more observations of surface wind velocity than ships/buoys ➢ Provides continuous, accurate , high resolution measurements ➢ Vital for climate research, operational weather forecasting, ocean storm warnings	MA 8
		No	Accept MetOp ASCAT (50kM) & MIS (TBD) reduced capability for the mid-AM orbit through 2020 AND Accept no coverage in mid-AM orbit beyond 2020 unless MetOp follow-on is approved and developed	Application ➢ Degraded hurricane model initial analysis leading to reduced intensity and forecast accuracy ➢ MIS provides spread, not direction ➢ Poorer resolution @ 50kM	

Part I: Proposed Actions for the Projected Satellite Program					
Timeline	**Inherent Strategic Actions for NOAA's Satellite Mission**	**If**	**Then**	**Impacts** **Application Impact**	**Technical Ref to Appendix E** **(MA=measure -ment area)**
2008	Follow-On Program for Altimetry (NASA Jason-1/ OSTM) with 2014 launch date Program Nomenclature: Jason-3 and Follow-On Relates to trade study for: Combined Altimetry / Scatterometry Mission	Yes	Assumes continuity measures for climate levels, Coastal Management, Disaster Management, Maritime Transport AND Assumes 3 altimeter constellation in partnership with JAXA and EUMETSAT. The US altimeter is in non-sun synchronous orbit, while the other 2 altimeters are in sun, synchronous orbit. This will accomplish SSH and Bathymetry mission.	Application ➢ Determine global variability of ocean circulation ➢ Tracking ocean circulation/thermal transport ➢ Measuring sea-level rise ➢ Tracking coastal ocean currents ➢ Predicting the severity of hurricanes	MA 9
		No	International partnership for data buy from SARAL-Sentinel series would be required to obtain SSH from the satellite platform	Application ➢One altimeter will not meet NOAA's requirement ➢Courser resolution and reduced capability	
2008	EUMETSAT Decision to upgrade to VIIRS-like instrument	Yes	Mid-AM polar orbit will be covered by EUMETSAT with ESA provided upgraded instrument	Continuity of Measurement for Imagery/Vis & IR, Ocean Color	MA 1 & 11
		No	Accept no mid-orbit coverage OR Provide GFE VIIRS-like instrument to EUMETSAT	Applications ➢Refresh rate at 6H (required 4H) ➢Degraded weather forecasts and precipitation type identification ➢Degraded forecast accuracy for hurricane intensity and tsunami warnings ➢Reduced accuracy for ocean specification for numerical models OR Continuity of Measurement for Imagery/Vis & IR, Ocean Color	
2008	Re-manifest earth radiation budget instrument onto NPOESS C3 and beyond or other satellite. Relates to trade study for: Combining climate sensors onto one satellite (free-flyer)	Yes	Establish global, long-term climate records that are of high accuracy and tied to international standards maintained in the U.S. by the National Institute of Standards and Technology (NIST) when used in conjuction of solar irradiance instrument	Application ➢Downward LW radiation (surface) ➢Downward SW radiation (surface) ➢Net Solar radiation of TOA ➢Outgoing LW radiation (of TOA) ➢Contribute To: Atmospheric vertical moisture & temperature profiles and Pressure (Surface & Profile)	MA 13

Part I: Proposed Actions for the Projected Satellite Program					
Timeline	**Inherent Strategic Actions for NOAA's Satellite Mission**	**If**	**Then**	**Impacts** **Application Impact**	**Technical Ref to Appendix E** **(MA=measure -ment area)**
		No	Accept lack of earth radiation budget instrument after 2018 for climate forecasting AND Consider Climate Satellite Free-Flyer	Discontinuous satellite record and degraded capability for global & mesoscale energy balances resulting in reduced mesoscale forecast accuracy and climate trend accuracy	
2008	Re-manifest aerosols Polarimeter instrument onto NPOESS and beyond or other satellite. Relates to trade study for: Combining climate sensors onto one satellite (free-flyer)	Yes	Narrow the uncertainty in climate predictions and improve the capability of models to provide more precise local predictions of climate change including changes in rainfall	Application ➢ Aerosol refractive index/ single scattering albedo & shape ➢ Cloud particle size distribution ➢ Contribute To: Precipitable water/ Integrated water vapor, Total water content, Cloud ice water path, and Cloud liquid water	MA 14
		No	Accept lack of aerosol polarimeter instrument data after 2013 (end of life for NASA GLORY Mission) AND Consider Climate Satellite Free-Flyer	Diminished accuracy of aerosol optical depth leading to decreased forecast accuracies of visibility, pollution impacts, etc.	
2008	Re-manifest ozone profile instrument onto NPOESS and beyond or other satellite. Relates to trade study for: Combining climate sensors onto one satellite (free-flyer)	Yes	Obtain high resolution global measurements used in modeling the chemistry and dynamics across the lower atmosphere ➢ Forecast chemical weather, air quality, and surface UV radiation ➢ Provide global trends important to all segments of society	Measure: Ozone Profile	MA 15
		No	Accept reduced forecast skill for the atmospheric vertical energy distribution AND Consider Climate Satellite Free-Flyer	Inability to measure ozone profile to compliment the Total Ozone measurement, decreases the ability to track ozone change and make predictions for public safety	
2008	Re-manifest solar irradiance instrument onto NPOESS C3 and beyond or other satellite. Relates to trade study for: Combining climate sensors	Yes	Establish global, long-term climate records that are of high accuracy and tied to international standards maintained in the U.S. by the National Institute of Standards and Technology (NIST) when used in conjunction with earth radiation instrument	Measure: Solar Irradiance	MA 16

Part I: Proposed Actions for the Projected Satellite Program					
Timeline	**Inherent Strategic Actions for NOAA's Satellite Mission**	**If**	**Then**	**Impacts** **Application Impact**	**Technical Ref to Appendix E** **(MA=measure -ment area)**
	onto one satellite (free-flyer)	No	Accept diminished capability to determine the global energy balance, reduces regional prediction accuracy AND Consider Climate Satellite Free-Flyer	Discontinuous satellite record of solar constant observations leading to decreased energy balance accuracy and related climate trend identification	
2009	Award post PDR GOES-R contract for development	Yes	Provide improved remote sensing capability from the geostationary orbit	Improved satellite service across all NOAA mission goals	
		No	Accept interruption to all environmental data records from the geostationary orbit	Discontinued continuous monitoring capability impacting all weather forecast activities	
2009	Participate in COSMIC (GPS Radio Occultation) Follow-on	Yes	Increased ability to accurately specify temperature and moisture profiles near tropopause and stratosphere		MA 21
		No	Accept degraded global and regional model skills	Accept degraded capability	
2010	Perform AoA to determine option to satisfy the requirement (i.e. synthetic aperture radar)	Yes	Increased ability to estimate the effects of greenhouse gases on the future global climate		
		No	Accept a reduced understanding of the interaction between greenhouse gases and climate change variability		
2012	Commit to GOES T&U with new advanced sounder capability	Yes	Improve severe storm forecasting and warning system	Atmospheric Moisture/Temperature Profiles	
		No	Accept current accuracy as 'good enough'		

Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2008		Evaluate methods to obtain OSVW (Scatterometry Mission)	**Operations Assessment:** Determine data recovery and operational usage of EUMETSAT's MetOp Advanced Scatterometer	Degradation of the weather forecasting and warning capability from operational utilization of the QuikSCAT	➢ Additional improvements in forecasting and warning capability will not be realized
	2009		**Capability Assessment:** Determine design of scatterometry satellite (i.e. XOVWM from decadal survey) to measure Ocean Surface Vector Winds	Improved resolution and coverage for coastal management, ecological forecasting, and invasive species Replace measurements from old research satellite, QuikSCAT, that is used for hurricane intensity and direction forecast and hurricane monitoring	➢ Improved near-shore coastal coverage and high-wind retrievals
	2011		**Commit to Program:** Accept design		
2008		Evaluate Calibration/ Validation Methods for climate measurement accuracy from satellites	**Capability Assessment:** Determine the priorities for Climate Data Records	Improved measurements to support climate requirements and independent validation and acceptance of sensor performance, both pre- and post- launch	➢ Insufficient accuracy to continue monitoring climate data for climate variability and causes
	2010		**Operations Assessment:** Determine the number of in-situ systems required to provide ground truth for satellite observations		
	2011		**Commit to Program:** Accept design		
2008		Determine best method for an integrated ground system	**Capability Assessment** : Determine a prototype hardware and software testing system that can support multiple satellites from multiple locations	A ground system that is adaptable to new and diverse missions and interoperable with the US GEO and GEOSS network	➢ Provide flexible ground capability for multiple satellites
	2010		**Operations Assessment:** Establish a commercial bus architecture		
	2011		**Commit to Program:** Accept design		

Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2008		Determine if space environmental requirements at a L1 Libration Orbit should be developed as a follow-on to the NASA ACE solar wind mission	**Capability Assessment:** ACE (NASA)--Review space environmental orbit options capability to determine requirement for a long-term solution	Improve understanding on how to predict changes in the solar atmosphere at the sun, and how they evolve as they expand outward into the solar system and into the Earth's magnetosphere and atmosphere.	➢ Reduce loss of radar and communications equipment which ultimately impacts reliable communications to precision navigation, limit military maneuvers, impede disaster recovery.
	2011		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2012		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2008		Participate in COSMIC Follow-on	**Capability Assessment:** Determine best alternative for a acquiring radio occultation information for operational use	Continue the capability for Global high resolution precipitation mapping (measurements of the vertical structure of electron density in the ionosphere, temperature in the stratosphere, and temperature and water vapor in the troposphere)	➢ Acquire Radio Occultation information ➢ Profiles of pressure, temperature and humidity versus height ➢ Very high precision time measurements ➢ All-weather conditions
	2009		**Commit to Program:** Determine commitment for operational usage and execution of development or commercial buy for measurements beyond 2015		
2008		To combine climate sensors onto one satellite (free-flyer)	**Capability Assessment:** Determine whether or not the climate sensors should be re-manifested on to the NPOESS satellites, fly as 'flights of opportunities', or partner with NASA to develop a free-flying constellation of climate satellites	Climate data records co-registered from a single source in time and location	➢ Partner with NASA to develop and demonstrate a free-flyer satellite application with intensions for turnover to NOAA ➢ AND ➢ Increased accuracy for climate data used by environmental impact policy makers.
	2010		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2011		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2008		To determine if ocean bottom topography can be accomplished using a space-based platform to meet NOAA requirements.	**Capability Assessment:** Bathymetry--Feasibility study, including benefit analysis, to determine sensing platform	Capability to measure and calculate the ocean bottom topography or contour depth charts quicker, with higher reliability, and in sparse regions from a space-based platform; vice ships and sonar with limited resources and limited coverage.	➢ Increase navigation chart accuracy, ocean modeling and prediction, and safe maritime passage ➢ Improve the understanding of currents, deepwater mixing, current steering, and their effects on climate
	2010		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2011		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2008		To combine altimetry/scatterometry missions onto one satellite	**Capability Assessment:** Combined Altimetry/Scatterometry Mission--Feasibility study, including benefit analysis, to determine if mission can be combined with Jason Altimetry Mission	Determine the feasibility to partner with international constituents for a combined altimetry mission for SSH and Bathymetry. Capability to measure and calculate the ocean bottom topography or contour depth charts quicker, with higher reliability, and in sparse regions	➢ Increase navigation chart accuracy, ocean modeling and prediction, and safe maritime passage ➢ Improve the understanding of currents, deepwater mixing, current steering, and their effects on climate
	2010		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2011		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2008		OIIP Decision to approach NASA for future system development and demonstration missions with contract option for follow-on satellite or instrument	**Capability Assessment:** Carbon (OCO launch 2008)--Feasibility study, including benefit analysis, to determine sensing platform	Determine feasibility of the NASA OCO mission which would provide the capability (meeting NOAA's requirements) to collect precise global measurements of carbon dioxide (CO_2) in the Earth's atmosphere to improve understanding of the natural processes and human activities that regulate the abundance and distribution of this important greenhouse gas	➢ Enable more reliable forecasts of future changes in the abundance and distribution of CO_2 in the atmosphere
	2009		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2010		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2008			**Capability Assessment:** Precipitation Type (GPM launch 2010)--Feasibility study, including benefit analysis, to determine sensing platform	Determine the feasibility of the NASA/JAXA GPM mission to provide all-weather information about the hydrological cycle such as latent heat release and the affect on storm dynamics, circulation and atmospheric structure. Advanced instrumentation that will be analyzed includes the Dual-frequency Precipitation Radar (DPR) and Passive Microwave Radiometer.	➢ Improve hydrological forecast for fresh water, agriculture, and water management. Forecast would include but not be limited to: droughts, floods and winter storms
	2011		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2012		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2008			**Capability Assessment:** Ocean Salinity (Aquarius launch 2009)--Feasibility study, including benefit analysis to determine sensing platform	Determine the feasibility of the NASA AQUARIUS mission to provide measurements of global Sea Surface Salinity (SSS) that will meet NOAA's requirements	➢ Improved understanding of the links between the water cycle, the climate, and the ocean.
	2010		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2011		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
					➢
2009		To determine if soil moisture should be accomplished using a space-based platform to meet NOAA requirements.	**Capability Assessment:** Soil Moisture: Feasibility study, including benefit analysis, to determine sensing platform SMAP (Decadal Survey)	Monitor evaporation and transpiration at the land-atmosphere boundary, soil freeze and thaw state, and improve the understanding of the linkage between terrestrial water, energy, and carbon cycle AND Provide climate data for carbon budget	➢ Reduce the uncertainty in flood predictions, landslides, and all-weather forecasts
	2011*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2012*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2009		To determine if 3D wind measurements should be accomplished using a space-based platform to meet NOAA requirements.	**Capability Assessment:** Tropospheric Winds--Feasibility study, including benefit analysis, to determine sensing platform 3-D Winds (Decadal Survey)	Determine the feasibility of obtaining three dimensional (3-D) wind data for improved weather (including over ocean) forecast and long-term analysis of systems (including severe storm) development over oceans	➢ Improved numerical weather predictions
	2010*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2012*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2009		To determine if a Coastal Event Monitor should be added to the NOAA satellite constellation	**Capability Assessment:** Coastal Waters/Habitat--Feasibility study, including benefit analysis, to determine sensing platform GEO-CAPE (Decadal Survey)	Capability to determine the impact of climate change and anthropogenic activity on primary productivity and ecosystem variability along coastal regions.	➢ Satellite observations for modeling and forecasting capabilities for ecological and biogeochemical processes in coastal ecosystem management.
	2015*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2019*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2010		Determine partnership viability for a Synthetic Aperture Radar	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	Capability to determine the impact of climate change though improved polar ice surface deformation and inundation extent determinations. For over oceans, the SAR would provide improved wind, ocean features, and ship detection.	Improvement to polar and Artic maritime passage forecast; and, rapidly changing ice coverage conditions (climate records) and ice type identification
	2016*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2019*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

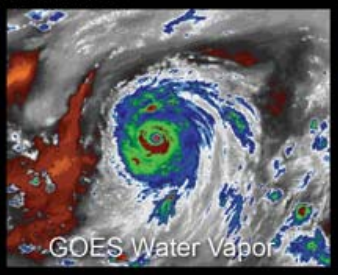
Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2012		To determine if snow depth should be accomplished using a space-based platform to meet NOAA requirements.	**Capability Assessment:** Snow Depth--Feasibility study for active sensor, including benefit analysis, to determine sensing platform SMAP (Decadal Survey)	Determine feasibility of using active sensor for snow depth mission which would significantly improve spatial resolution for snow depth data (more than snow water equivalent only)	➢ Improve hydrological management for snowmelt, floods, and water supply predictions
	2014*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2016*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2012		To determine if ice thickness should be accomplished using a space-based platform to meet NOAA requirements.	**Capability Assessment:** Ice thickness--Feasibility study , including benefit analysis, to determine sensing platform ICESat (Decadal Survey)	Determine the feasibility of a research mission to continue to monitor sea ice thickness as a follow-on to the ICESat mission to improve understanding of ice interaction for climate variability	➢ Reduced errors in ice volume analysis and sea-level rise predictions
	2013*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2015*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2015		To determine if very high spatial resolution sensing should be accomplished by a NOAA satellite or if commercial data buys should continue.	**Capability Assessment:** Very high spatial resolution sensing for ecosystems and special events management. Currently: com'l data buy ICONOS, ORBVIEW, SPOT	Determine the feasibility of a research mission to provide high and low spatial resolution sensor for economically important seafood species of harvesting, coastal land management, climate change, and extreme weather events. (i.e. aerosols, organic matter, phytoplankton) for ecological and biogeochemical processes in coastal ecosystems	➢ Improve air quality forecasts through chemical data assimilation, monitoring pollutant emissions and accidental releases, understanding pollution transport on regional to intercontinental scales, and coastal ecosystem health management for control of rapid proliferate toxins or nuisances (i.e. harmful algal blooms or red tides)
	2016*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2018*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2015		Determine if microwave sounding from a geostationary orbit should be added to the NOAA operational satellite constellation	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	Determine the feasibility to improve monitoring cloud microphysics and profiles and add capability with Stratospheric and Tropospheric Profiles	➢ Improve hydrometeor profiles for climate forcing, air quality, and numerical weather predictions
	2016*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2018*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2015		Determine feasibility of of Far IR Monitoring in the geostationary orbit	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	Determine the feasibility of a 4D Lighting and 3D winds capability to improve monitoring and prediction of aviation weather, flash floods warnings, hurricanes, marine weather, severe storm initiation/evolution, and winter storms. Determine companion measurement for ocean color to measure aerosol concentration type and vertical profiles to improve aerosol characterization for ocean color products	➢ Improved weather forecasting, coastal management and ecological forecasting
	2016*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2018*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2015		Determine feasibility of a Doppler Microwave Altimeter Mission	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	Capability to measure long-term changes in the volumes of ice sheets to sufficient accuracy to assess their impact on global sea level, and to measure seasonal and interannual variability of the surface elevation in sufficient spatial and temporal detail to permit identification of long-term trends and to help explain those trends	➢ Improve climate data relating to sea ice sheet elevation and the ability to determine ice surface characteristics. Determine sea surface topography for understanding ocean dynamics
	2016*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2018*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

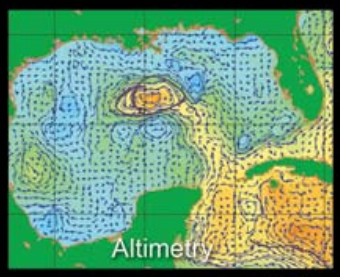
Part II: Trade Studies for the Projected Satellite Program					
Action Timeline		**Proposed Action**	**Satellite Trade Study Candidates**	**Anticipated Improvement**	➢ **Application Impact**
Trade	**Option**				➢
2018		Determine if a Laser Altimetry mission should replace ICEsat data	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	to measure long-term changes in the volumes of ice sheets to sufficient accuracy to assess their impact on global sea level, and to measure seasonal and interannual variability of the surface elevation in sufficient spatial and temporal detail to permit identification of long-term trends and to help explain those trends.	➢ Improve climate data relating to sea ice sheet elevation and the ability to determine ice surface characteristics. Determine sea surface topography for understanding ocean dynamics
	2019*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2020*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2018		Determine partnership viability for a wide-swath Altimeter mission capability	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	Ability to measure the storage and movement of water including ocean circulation and fine-scale bathymetry and sea floor roughness. (Spatial mapping of water surface elevations)	➢ Improve NOAA ocean bathymetry (currently done by fleet), river discharge estimates, and sea level mapping
	2019*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2020*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		
2025		Determine partnership viability for a Differential Absorption Lidar	**Capability Assessment:** Feasibility study, including benefit analysis to determine sensing platforms	Ability to improve measurements of vertical ozone profiles and critical ozone pre-cursors used to identify global aerosol/air pollution transportation and processes	➢ Improve the identification of sources and sinks of harmful pollutants ➢ Improve Ozone and surface radiation forecasts and Dangerous pollution events.
	2026*		**Operations Assessment:** Analysis to determine data recovery and operational usage benefits		
	2027*		**Commit to Program:** Determine commitment for operational usage and execution of development contract for follow-on option		

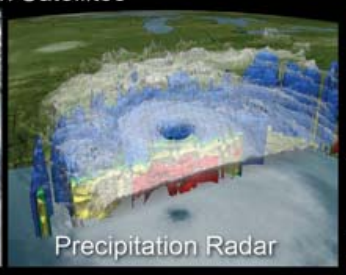
NOAA Observations...
Protect Life, Property, and Natural Resources

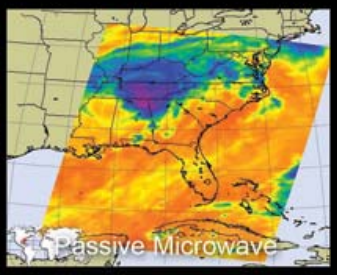
Operational Satellites



Research Satellites

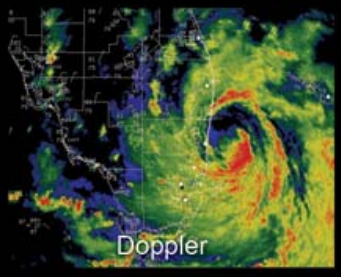


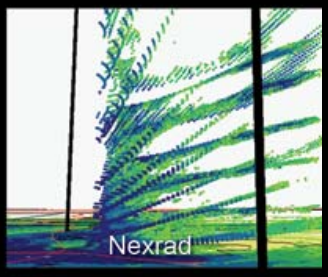




Building and maintaining state of the art satellite programs is an important component of NOAA's integrated observation efforts

Vice Admiral Conrad C. Lautenbacher, Jr., U.S. Navy (Ret.)
Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator





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